Science Waiting for Canada?

Sound Sightings

Scientists know much less about the lifestyles and travel habits of ocean dwellers than they do about most land animals. But newly developed systems based on acoustic sensing—one to track tagged fish and another to locate fish populations—promise to lay bare many secrets of the deep.

In late June, ocean scientists from about a dozen countries announced plans to set up a worldwide network of seafloor acoustic sensors, laid on continental shelves, to follow thousands of tagged fish. Another technology, soon to be tried out in the Gulf of Maine, relies on the acoustic properties of the relatively shallow coastal ocean to observe shoals of fish in real time.

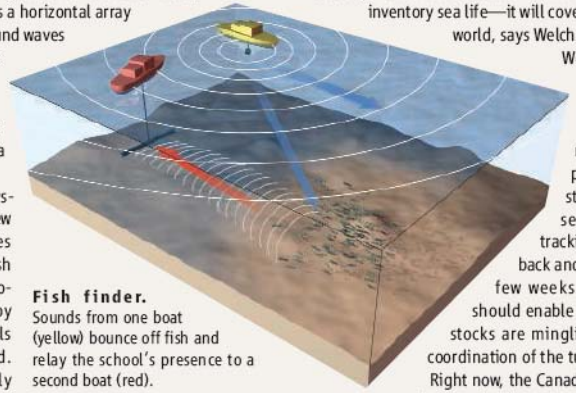
In addition to providing insights into fish movement patterns, large and small, both approaches promise to improve fisheries management. "For fish that do not come to the surface, [it's] the only way to get precise locations and habitat use data," says Kim Holland, a marine biologist at the Hawaii Institute of Marine Biology, who tracks tiger sharks.

Traditionally, researchers use sonar to locate fish. From a boat, they send high-frequency acoustic signals that bounce off a fish's air-filled swim bladder and reveal its location. But sonar tells little about fish distribution because it only detects those in a 10-meter-wide column of water. Nor does it yield much information about fish movements, says ocean engineer Nicholas Makris of the Massachusetts Institute of Technology in Cambridge.

As an alternative, Makris has developed Ocean Acoustic Waveguide Remote Sensing. The technique exploits the fact that the shallow coastal areas of the continental shelf, where the ocean averages less than 200 meters deep, act as a "waveguide," allowing sound to bounce relatively unattenuated between the water's surface and the sea floor. The sensing strategy requires two boats. Hanging off one, a vertical array of speakers emits low-frequency chirps that make the surrounding water vibrate "like a guitar string," says Makris. The other boat, several kilometers away, deploys a horizontal array of hydrophones that pick up sound waves deflected by the fish. The result is a constantly shifting two-dimensional image—like a weather radar image—of fish densities over a huge area (*Science*, 3 February, p. 660).

When Makris tested the system in 2003, off the coast of New Jersey, he and his colleagues were able to detect groups of fish over thousands of square kilometers. They watched minute by minute as schools and shoals formed, divided, and scattered. The technology is "extremely exciting, as it allows the identification of patterns of fish density over a very wide range of scales," says zoologist Iain Couzin of the University of Oxford, U.K. It could enhance data-gathering 1000-fold. This fall, Makris's group will head for the Gulf of Maine to help the National Marine Fisheries Service in its annual survey of North Atlantic herring.

Ready to transmit. A biologist implants an acoustic tag into an anesthetized salmon smolt.



Fish finder. Sounds from one boat (yellow) bounce off fish and relay the school's presence to a second boat (red).

CREDITS (TOP TO BOTTOM): PACIFIC OCEAN SHELF TRACKING PROJECT; C. BICKEL/*SCIENCE*

The proposed Ocean Tracking Network would use a different technology, underwater acoustic receivers and small acoustic tags, to tail far more fish and a greater variety of them far more cheaply than current satellite or ship-based tracking programs allow, says coordinator Ronald O'Dor, a biologist at Dalhousie University in Halifax, Canada. Satellites, for example, can track radio signals only when an animal is at the surface, and the flashlight-sized transmitters can be attached only to large fish and marine animals.

In contrast, the new network could track submerged animals, big and small, and would not require ships or satellites to pick up the signals. The test bed of the proposed network has been an array of underwater acoustic receivers called the Pacific Ocean Shelf Tracking Project (POST). Two years ago, fish biologists captured 2000 juvenile wild salmon spawned in rivers in Canada and the United States, surgically implanted them with small acoustic transmitters, and let them loose to make their way to the Pacific. There, the fish were monitored by soda can–sized sensors deployed in six 20-kilometer-long "listening lines" perpendicular to a 1500-kilometer stretch of Canadian coastline. The fish tags—acoustic equivalents of supermarket bar codes—last from 6 months to a couple of years. Fingernail-sized ones transmit only an ID, but larger tags daily record location, temperature, and depth and can dump the information when they come near a receiver, says oceanographer David Welch, head of POST. With such data, it may be possible to find the cause of a decline in salmon that hatch in the Columbia River, notes Ben Zelinsky of the Bonneville Power Administration in Portland, Oregon.

The international network will ultimately require about $167 million to set up. Part of the Census of Marine Life—a global 10-year initiative to inventory sea life—it will cover 14 ocean regions throughout the world, says Welch.

Welch, who runs Kintama Research Corp. on Vancouver Island in British Columbia, Canada, says the network could clear up fisheries management questions. For example, "European" and "American" stocks of bluefin tuna are managed separately. Yet, he notes, satellite tracking has shown that fish can "move back and forth across the Atlantic in just a few weeks." The Ocean Tracking Network should enable scientists to determine how those stocks are mingling, which should lead to better coordination of the tuna fisheries, he says.

Right now, the Canadians are on tenterhooks waiting to see whether they're going to get the $32 million they have applied for from the Canadian government to get the project rolling; many other countries whose researchers are involved in the effort are also being asked to chip in. "One of the most difficult things," says Welch, is persuading people "just how desperately we need this information—because we've never had it." **–C.H.**

UPDATES

1. $8M Canada IPY - $0
2. Australia IMOS - $4M
3. Canada Foundation for Innovation - $35M
4. NSERC Canada - $10M
5. SSHRC Canada - $0.5M
6. $100M Mexican mega-project proposal - $0
7. Caribbean LME UNEP - $7M
8. OTN named a GOOS Pilot Project by GSSC
9. NOAA IOOS proposal filed with CenCOOS
10. CoasTrack proposal to EU 7th Framework

CHANGES

1. Juggle CFI to cover IPY Arctic - delay Southern Ocean
2. NSERC for management & Canadian species/people
3. Initial focus on Pacific, Atlantic and Arctic Arenas
4. Advanced focus on 500m depth/daisy-chain receivers
5. DFO Halifax Line tests physical oceanographic sensors
6. NEPTUNE/VENUS to test cable links

IOC-XXIII/3, Annex II – p. 5, Resolution XXIII-3, 7/2005: CENSUS OF MARINE LIFE

The UN Intergovernmental Oceanographic Commission,

Noting the progress in the Census of Marine Life, a ten-year initiative over 2001-2010 to assess and explain the diversity, distribution, and abundance of marine life in the oceans,

Recognizing that scientists of Member States are taking an active part in the Census and that there are links to the Census through the International Ocean Data Exchange (IODE) and the Global Ocean Observing System (GOOS),

Acknowledging the Census of Marine Life as an important tool for the international community to gain information on marine life and as a provider of monitoring methods for marine life for GOOS,

Urges Member States, particularly those whose scientists are not already involved in the Census or in its Ocean Biogeographic Information System (OBIS) initiative, to support active participation, with a view to contributing to the achievement of the goals of the Census of Marine Life by 2010.

MARINE

Email, Phone, Data: All in One Fish

TRACKING MARINE LIFE WITH BLACKBERRY TECHNOLOGY

Photo courtesy of POST

For years we've had cell phones that take pictures and personal digital assistants that surf the Web and play music. If only we could put something like that on a fish to record its worldwide wanderings and send an occasional, fact-filled email. Consider it done. Almost.

The US$136-million Ocean Tracking Network, funded by the Canadian government and housed at Dalhousie University in Nova Scotia, will in effect equip fish with BlackBerry-like mobile devices that can store and send data via an array of sensors on the sea floor. It will even transmit data from one fish to another.

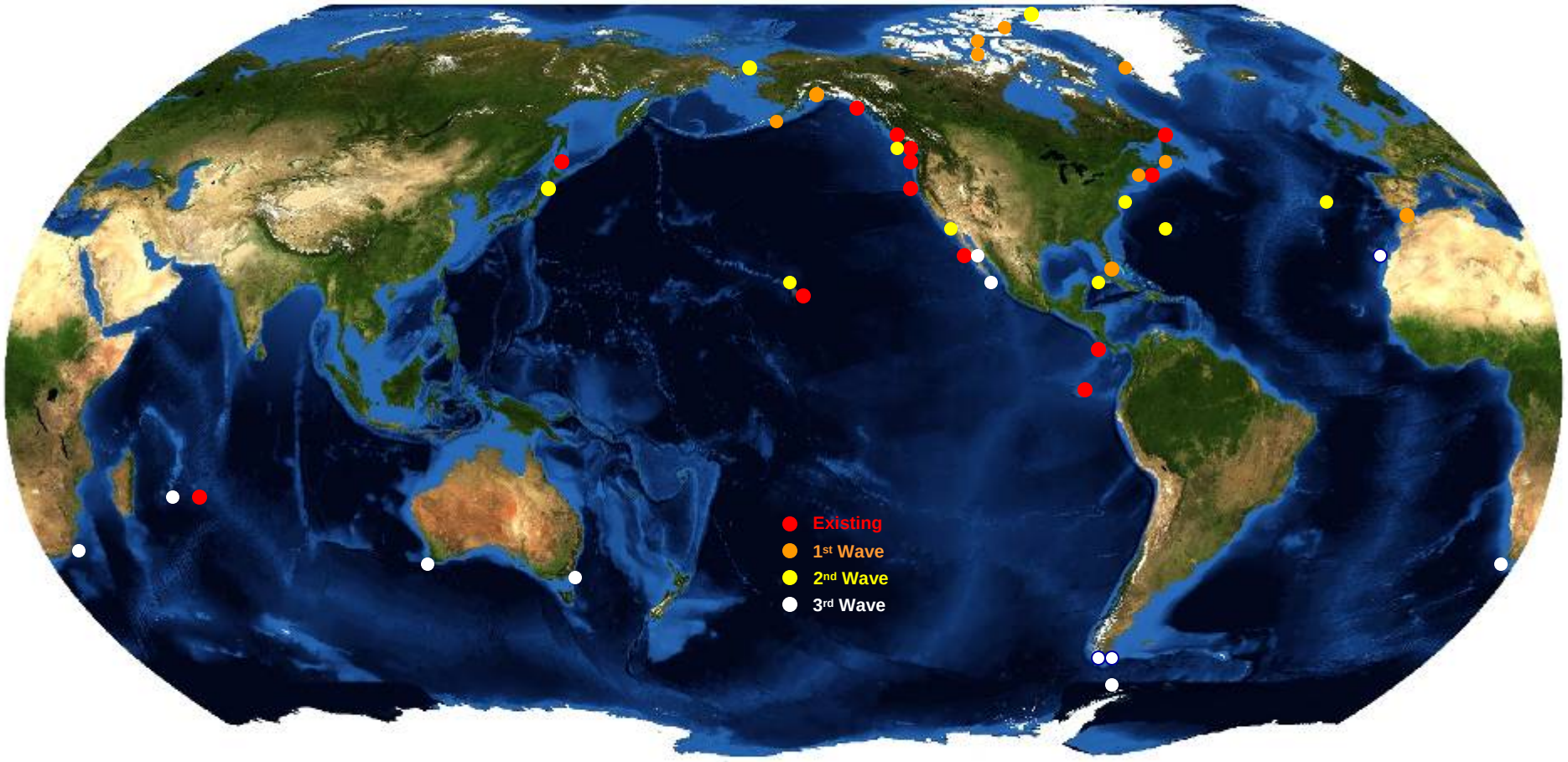
Researchers have been tagging and monitoring fish for decades, but with spotty results. For the most part, the habits and whereabouts of fish in the oceans have remained one of many mysteries of the deep. Much of what we do know about fish is from commercial and sport-catch records—which, ironically, means killing fish to learn they need to be saved.

The Ocean Tracking Network merges the acoustic-sensing technologies of two of the most successful electronic fish-tagging methods: the Pacific Ocean Shelf Tracking Project (POST) and the Tagging of Pacific Pelagics (TOPP).

POST researchers surgically implant acoustic transmitters the size of an almond into Pacific Northwest salmon smolts and California sturgeon. As the fish migrate through the oceans, the transmitters send out acoustic signals that are picked up by sensors strung in a trapline across the continental shelf. Sensors detect fish as they pass between Oregon and the north end of the Alaska panhandle. The tags' unique code identifies each individual fish and its location. "It's like an acoustic bar code," says Ron O'Dor, a Dalhousie professor and senior scientist for the Census of Marine Life, the network's principal researcher.

TOPP uses tags similar to computer memory sticks, collecting data from fish and marine mammals as they move and recording data such as depth, temperature, salinity, light, and location. The data are then beamed to an ARGOS satellite—either when the animal surfaces, the tag pops off, or the animal is captured and the tag recovered. More than 2,500 animals and nearly two dozen species have been tagged in the eastern Pacific Ocean. Researchers receive reports from hundreds of animals daily, says Barbara Block,

Global Ocean Tracking Network

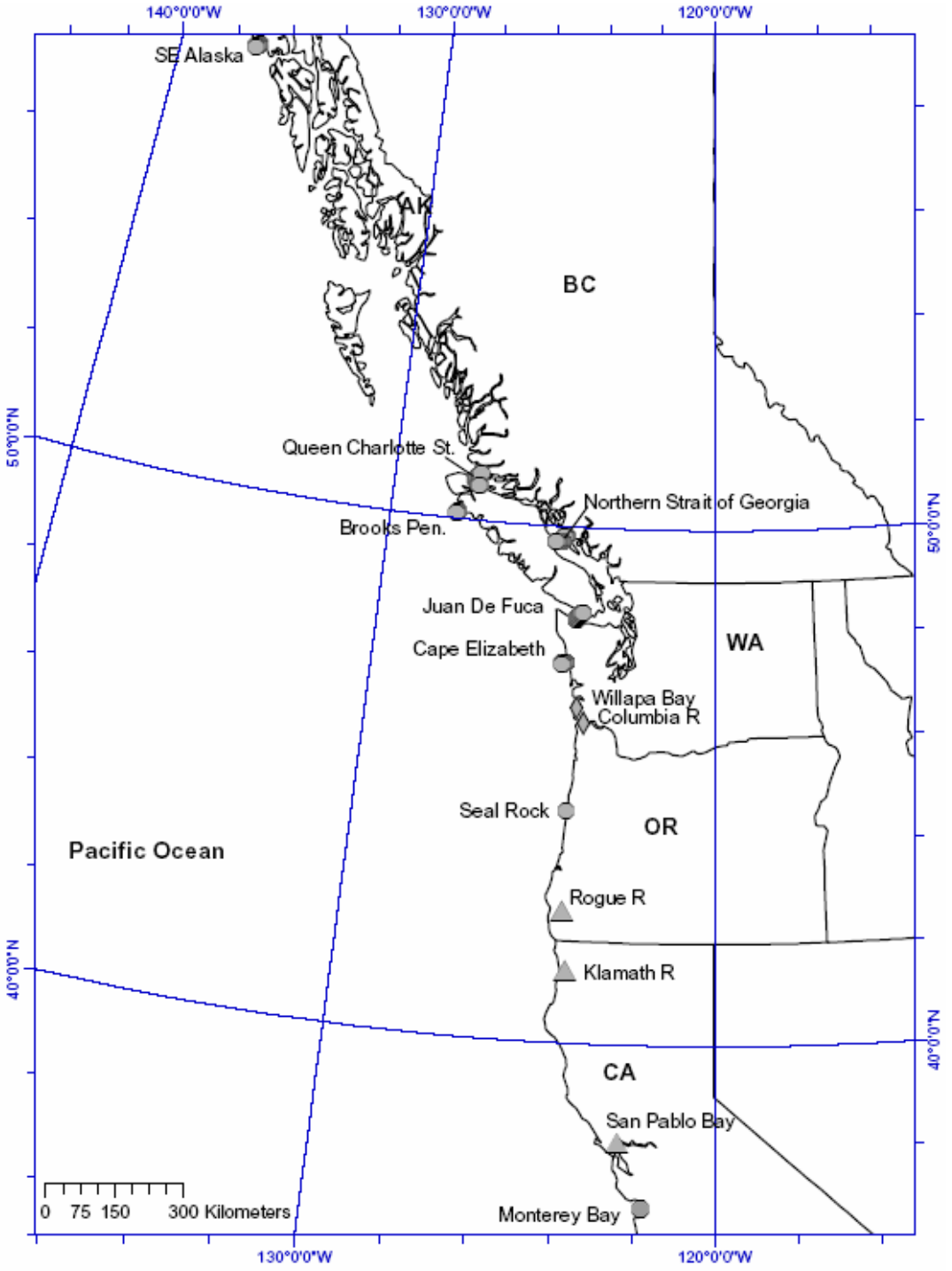


OCEAN TRACKING NETWORK

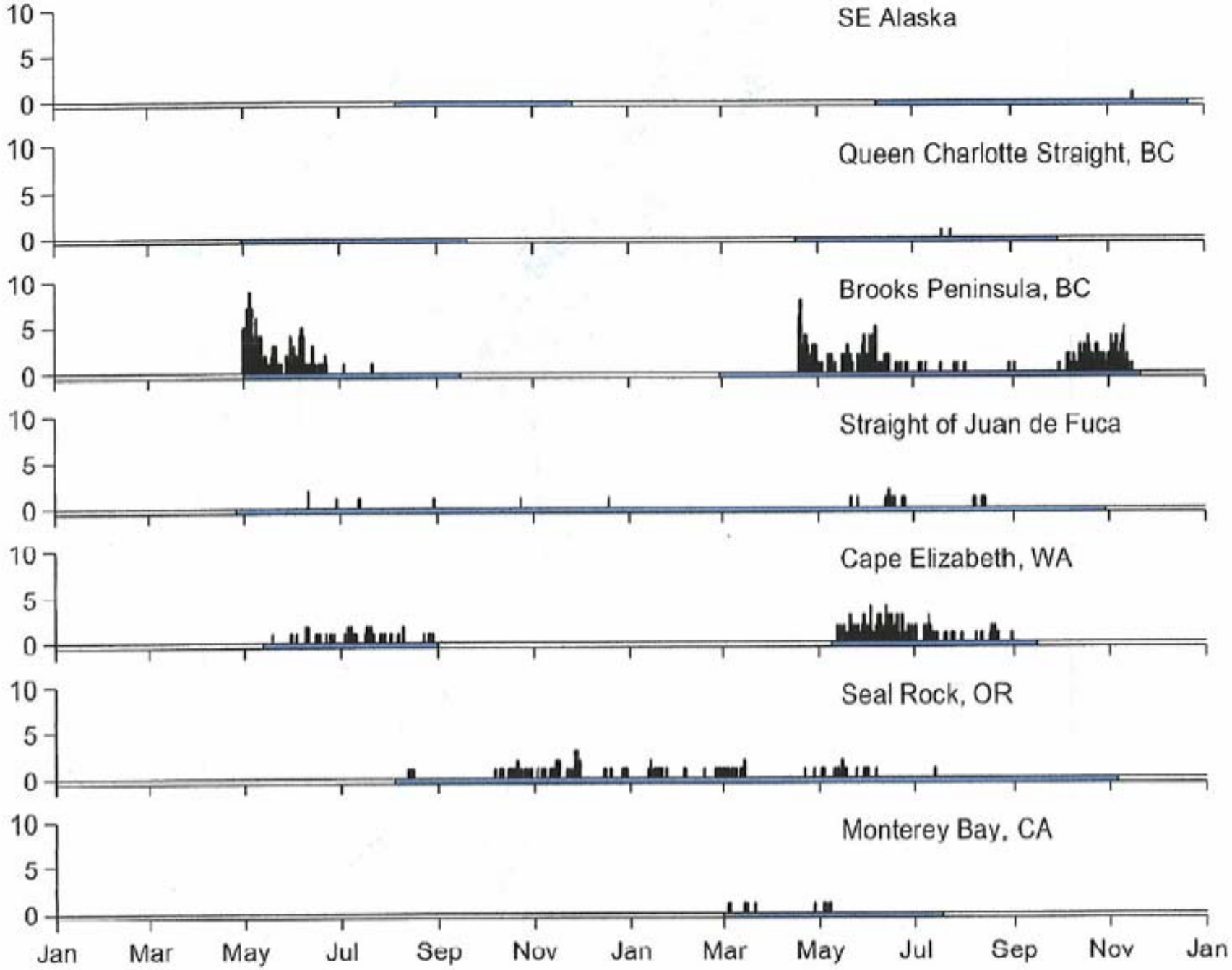
“Blackberries for fish” – GOOSberries?

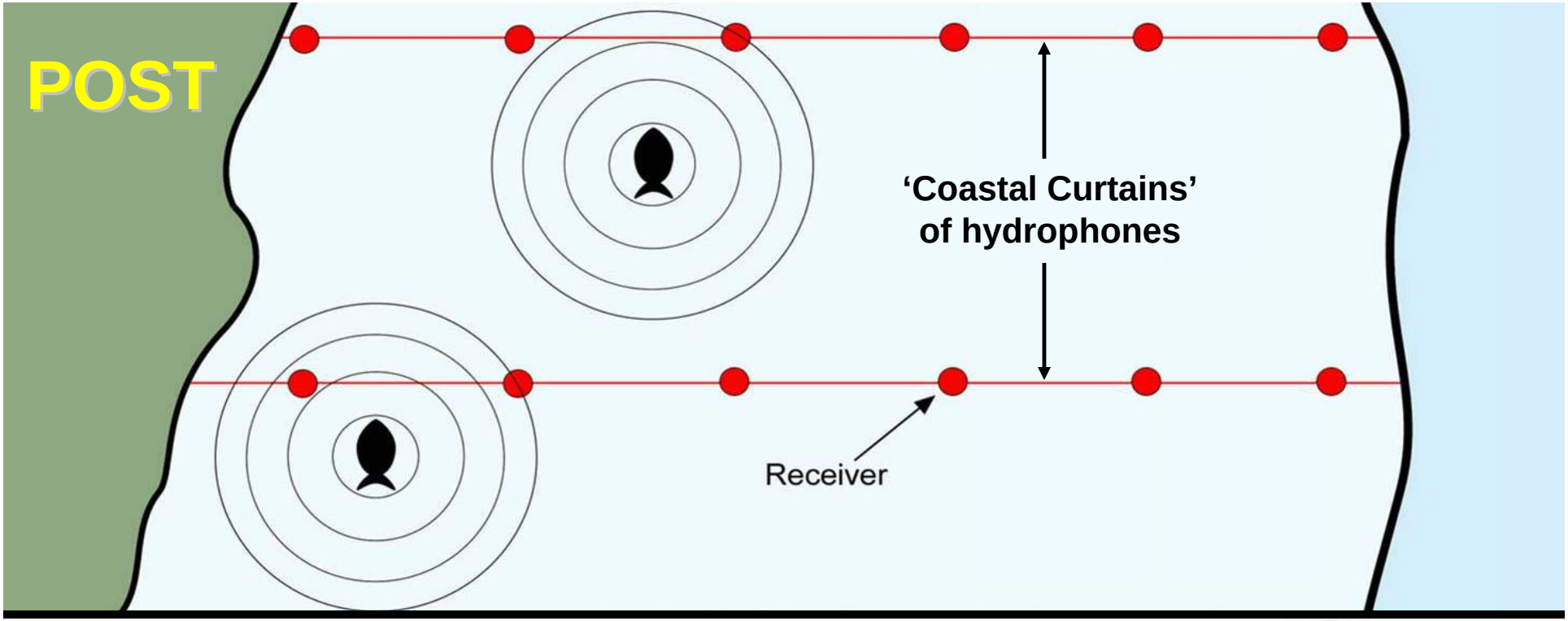
NOAA tracked threatened Green Sturgeon in POST System 2003-2006 Monterey, CA to Icy Straits, AK

(Lindley et al., in press)

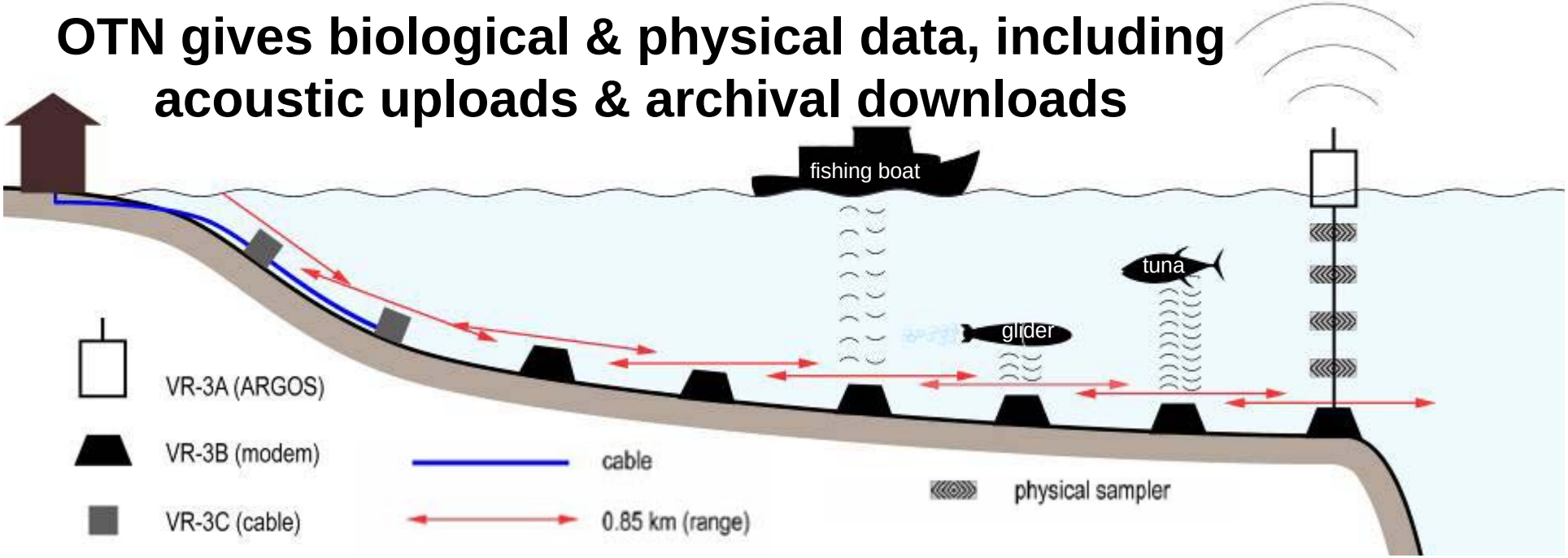


Green Sturgeon Migrations in POST – 2002 - 2004

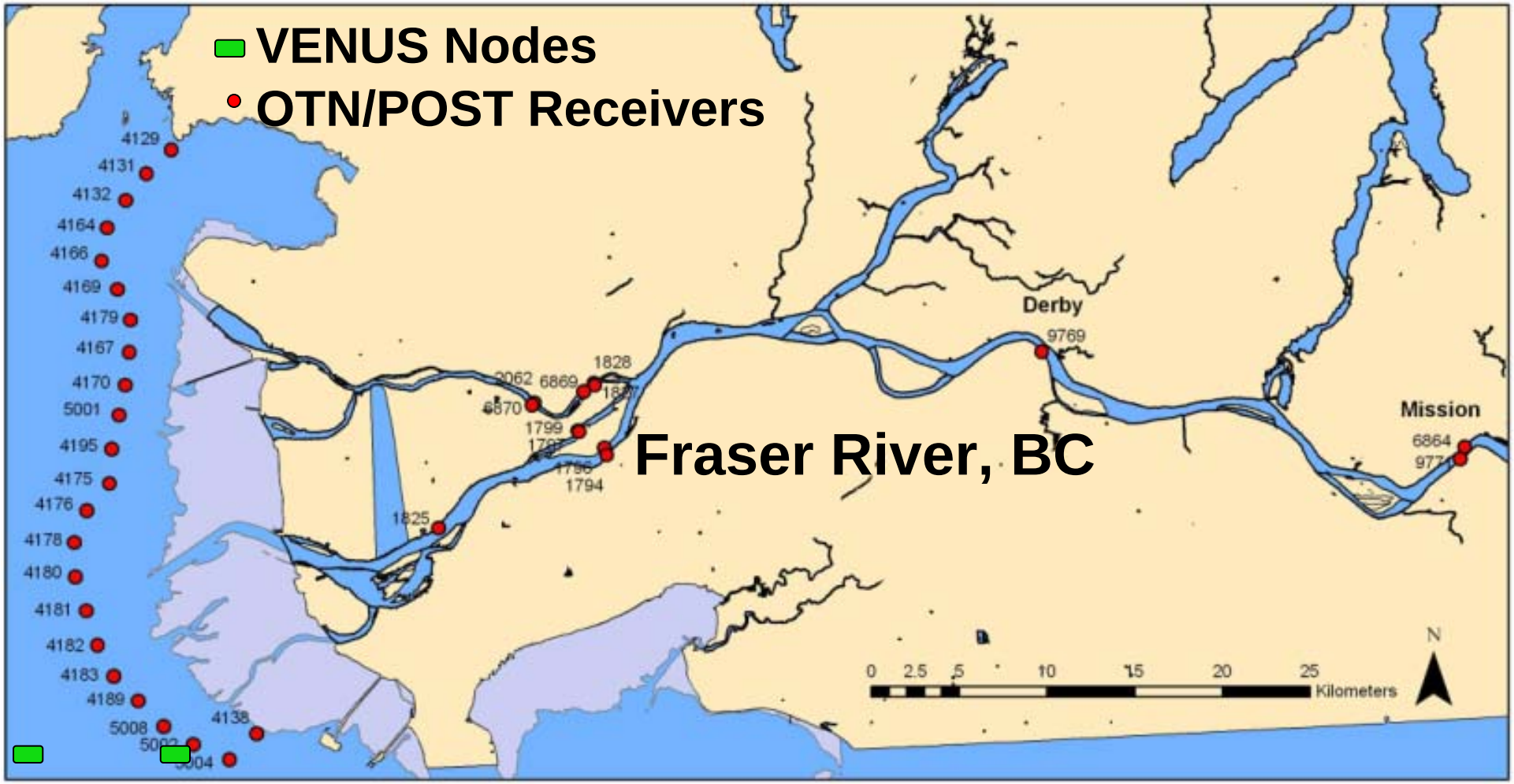


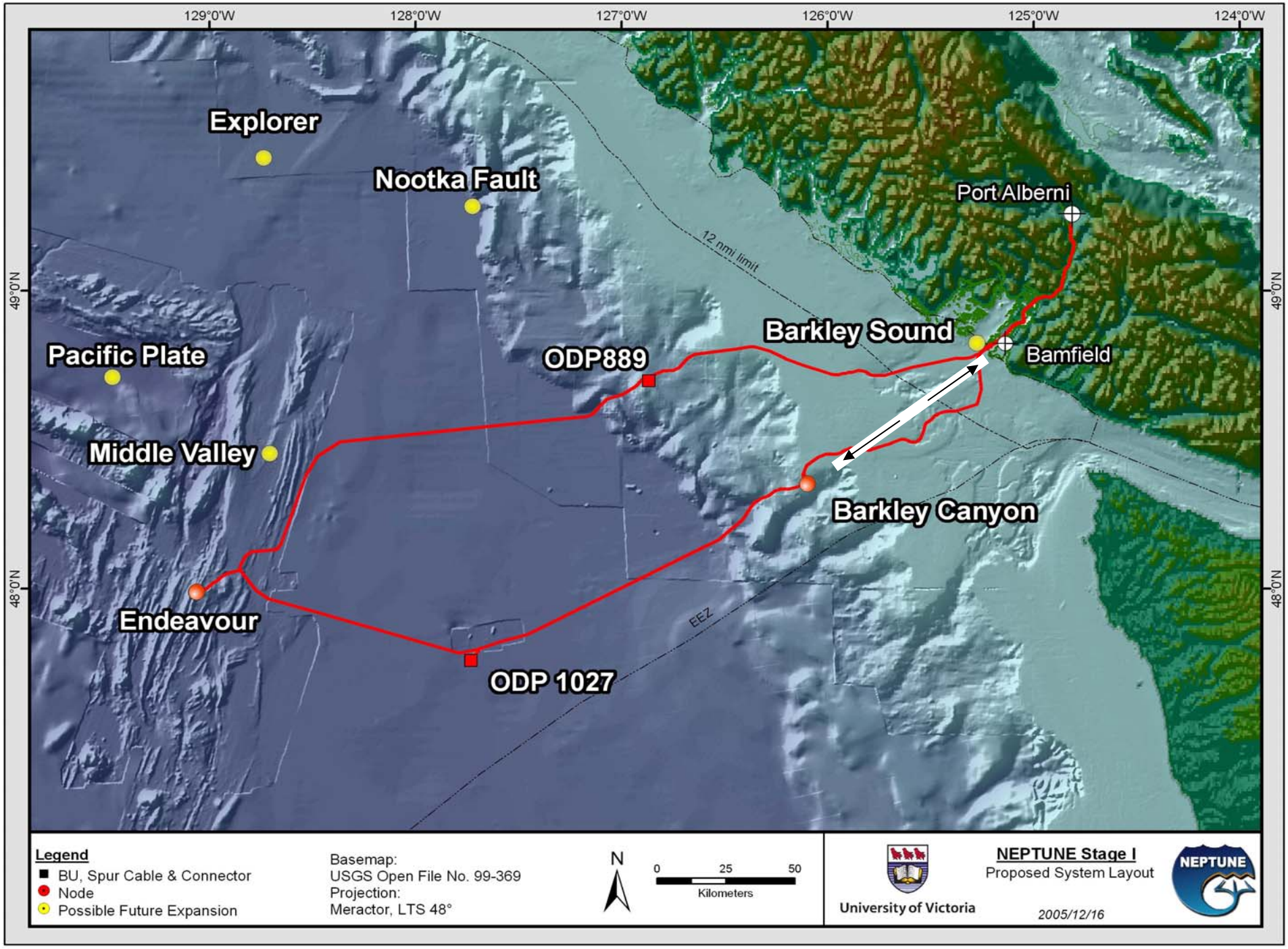


OTN gives biological & physical data, including acoustic uploads & archival downloads



Real Time Salmon Migrations
Satellite and Cable Links




129°0'W
128°0'W
127°0'W
126°0'W
125°0'W
124°0'W
49°0'N
48°0'N
Explorer
Nootka Fault
Port Alberni
12 nmi limit
Barkley Sound
Bamfield
Pacific Plate
ODP889
Middle Valley
Barkley Canyon
Endeavour
EEZ
ODP 1027
Legend
BU, Spur Cable & Connector
Node
Possible Future Expansion
Basemap:
USGS Open File No. 99-369
Projection:
Meractor, LTS 48°
N
0
25
50
Kilometers
University of Victoria
NEPTUNE Stage I
Proposed System Layout
2005/12/16
NEPTUNE

Bioprobes

Ecosystem-based Management

Fully Integrated Tags

- Send/Receive POST codes
- Geolocation
- Physics/Chemistry
- Acoustic download

1) I'm here . . .

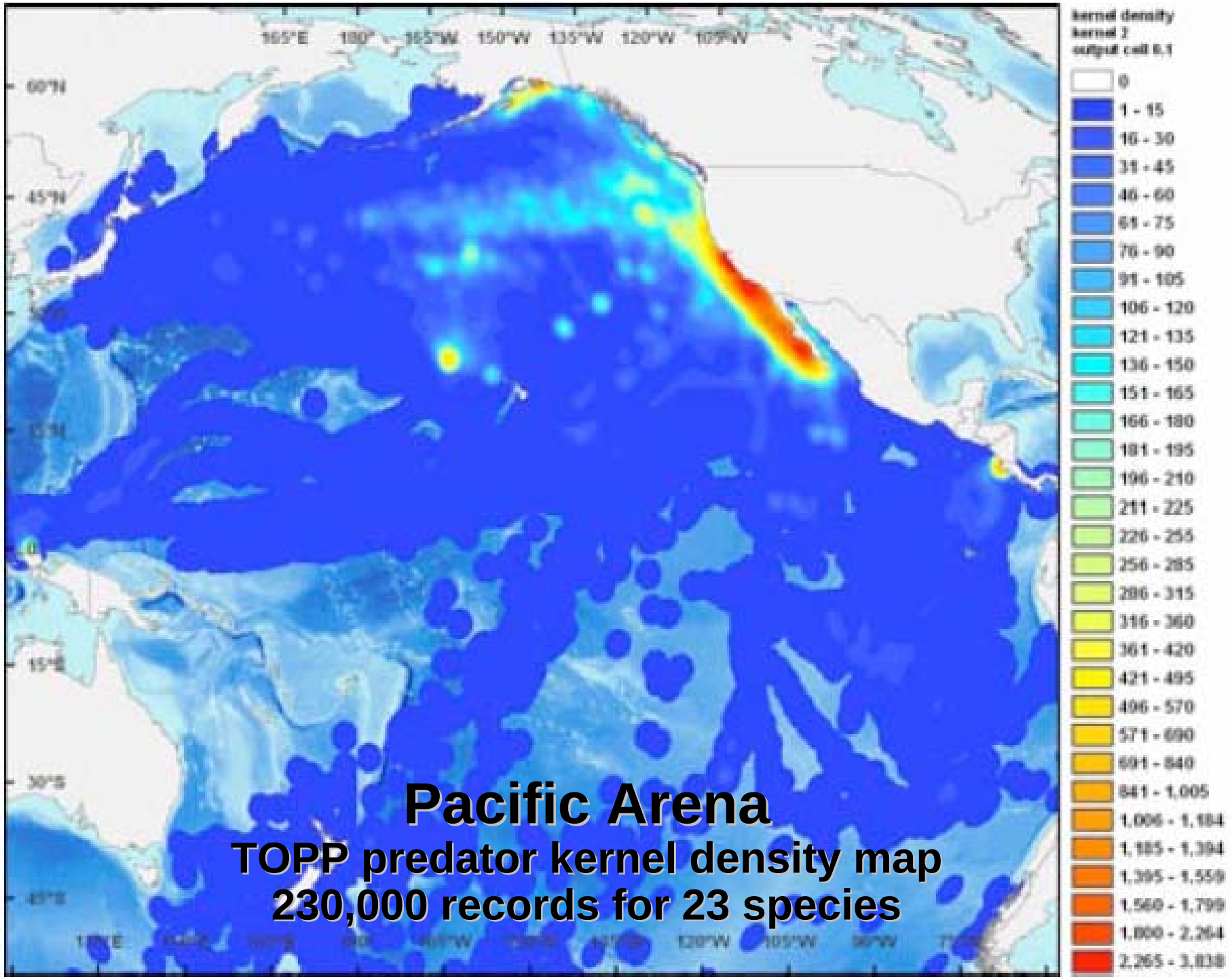
3) I've been to . . .
4) It was cold…
5) I met…
6) I ate…

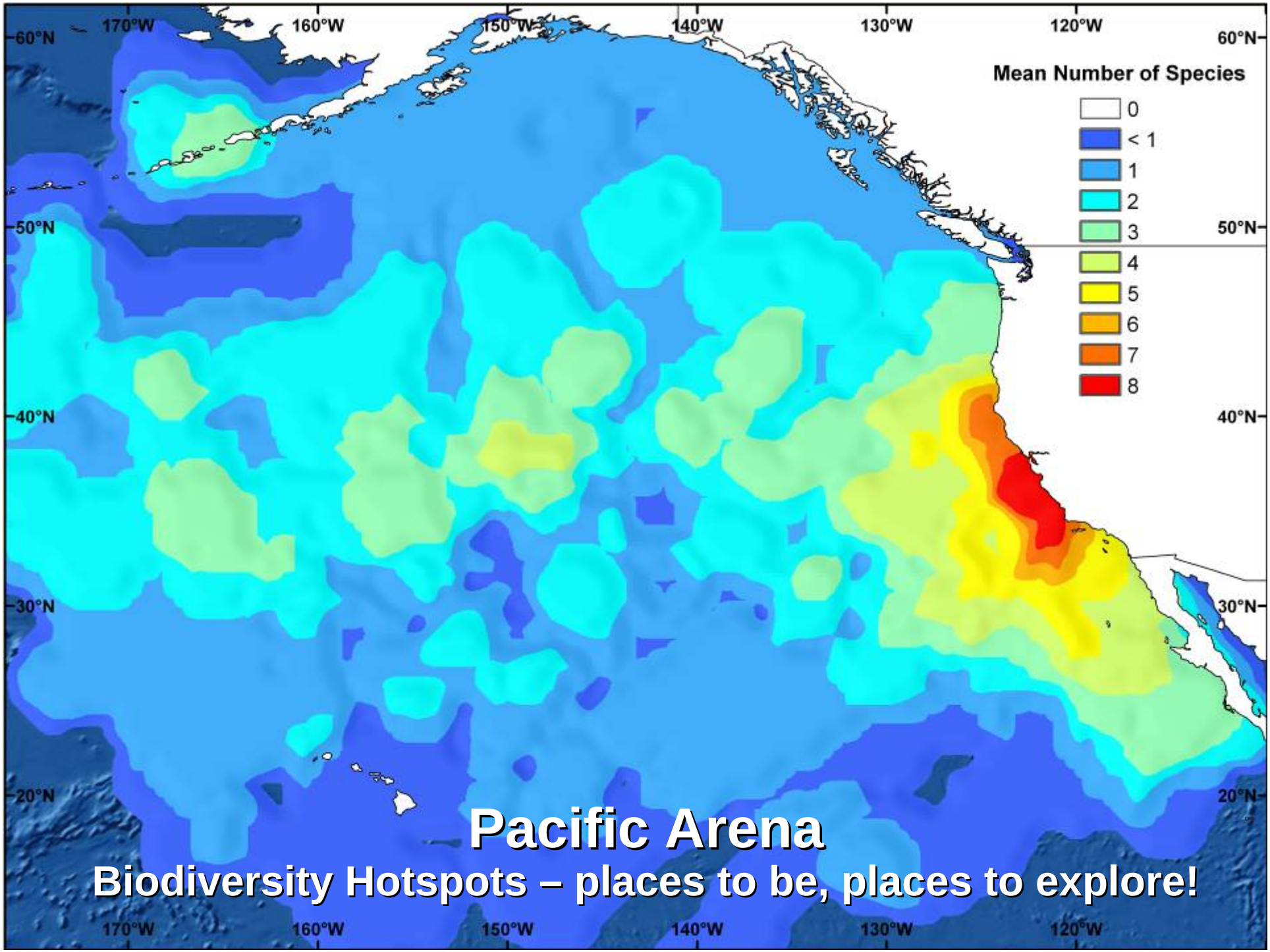
2) Where have you been?

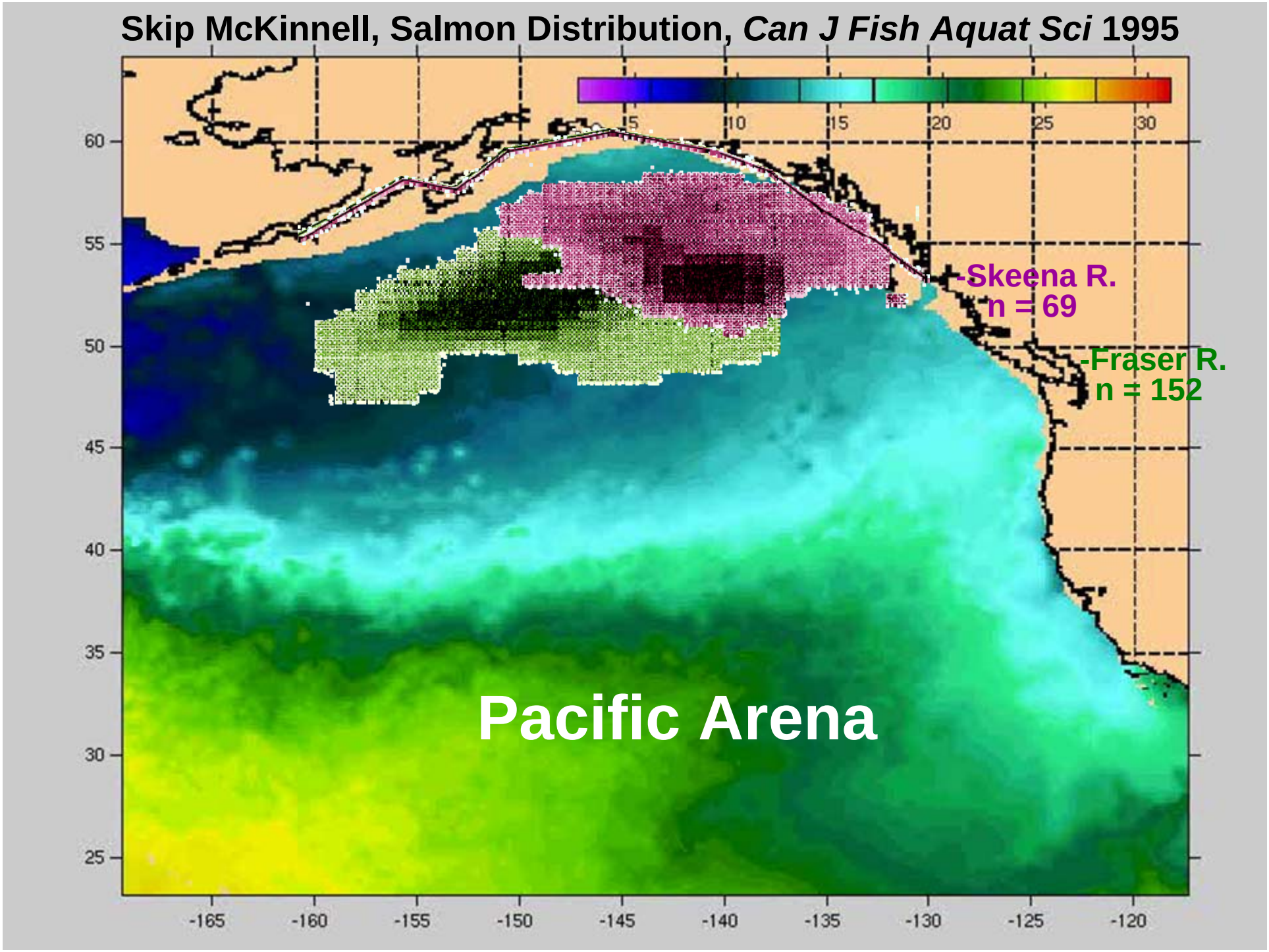
300 m

Data Logger

Holland, www.soest.hawaii.edu/PFRP/biology/dagorn_business_tags.html


kernel density
kernel 2
output cell 6.1
0
1 - 15
16 - 30
31 - 45
46 - 60
61 - 75
76 - 90
91 - 105
106 - 120
121 - 135
136 - 150
151 - 165
166 - 180
181 - 195
196 - 210
211 - 225
226 - 255
256 - 285
286 - 315
316 - 360
361 - 420
421 - 495
496 - 570
571 - 690
691 - 840
841 - 1,005
1,006 - 1,184
1,185 - 1,394
1,395 - 1,559
1,560 - 1,799
1,800 - 2,264
2,265 - 3,838
Pacific Arena
TOPP predator kernel density map
230,000 records for 23 species


Mean Number of Species
0
< 1
1
2
3
4
5
6
7
8
60°N
50°N
40°N
30°N
20°N
170°W
160°W
150°W
140°W
130°W
120°W
Pacific Arena
Biodiversity Hotspots – places to be, places to explore!

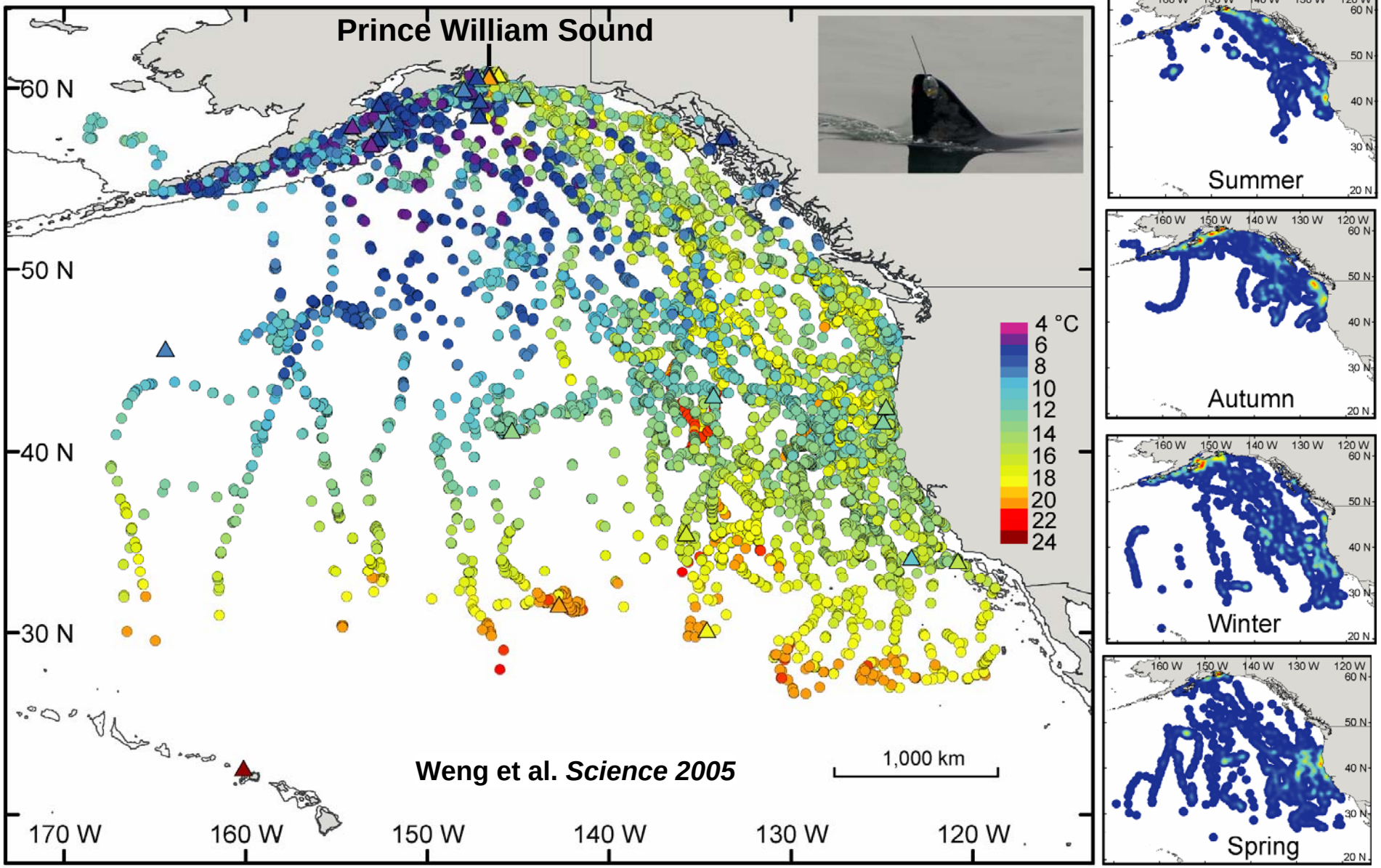

Skip McKinnell, Salmon Distribution, *Can J Fish Aquat Sci* 1995
5
10
15
20
25
30
60
55
50
45
40
35
30
25
-165
-160
-155
-150
-145
-140
-135
-130
-125
-120
-Skeena R.
n = 69
-Fraser R.
n = 152
Pacific Arena

Salmon Sharks
TOPP secret weapon #1

Most days these shark fins emerge and talk to satellites

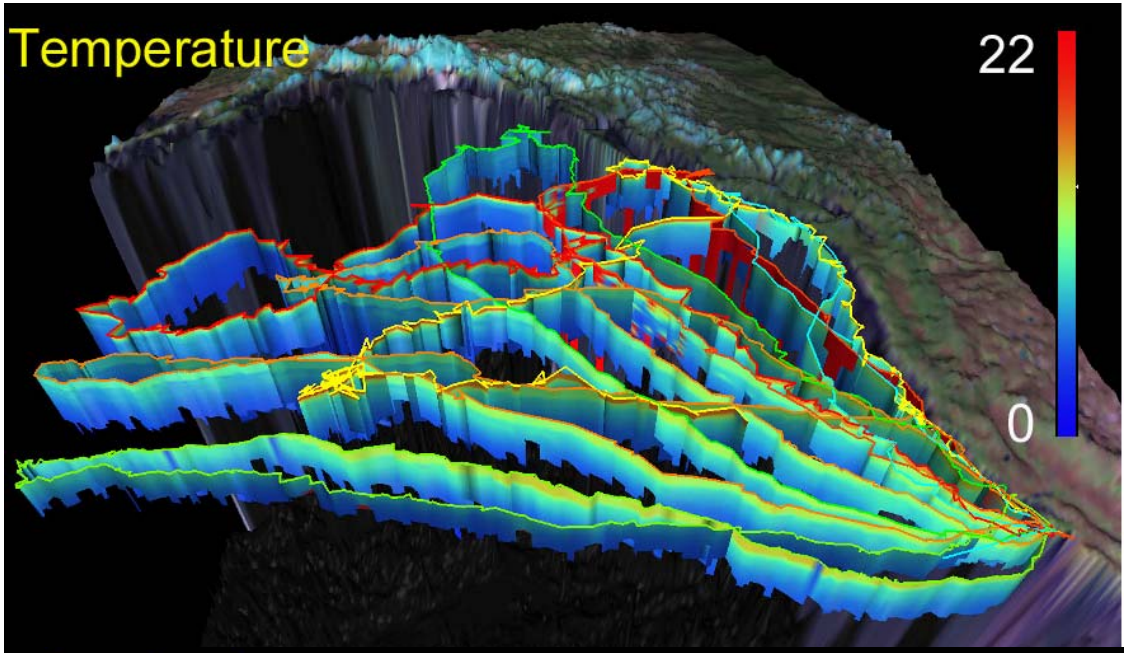
TOPP
Tagging Of Pacific Pelagics

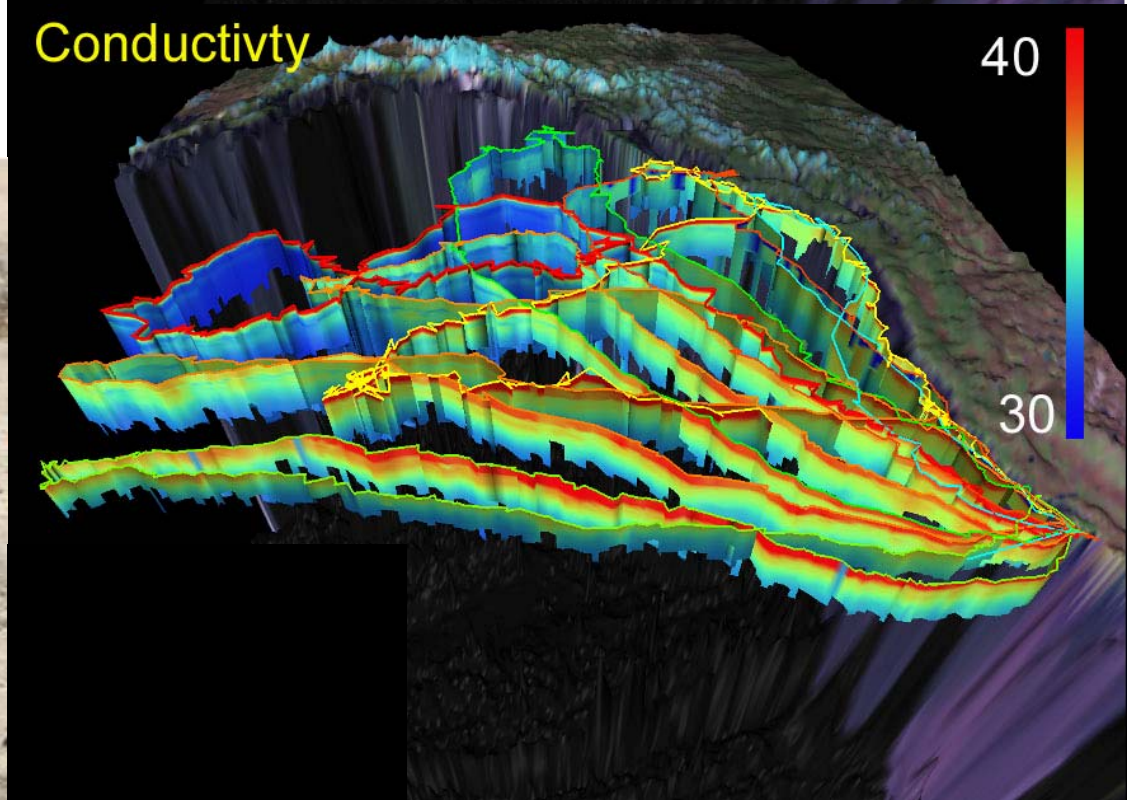
Salmon Shark ranges overlap NE Pacific ranges for most salmon stocks at sea

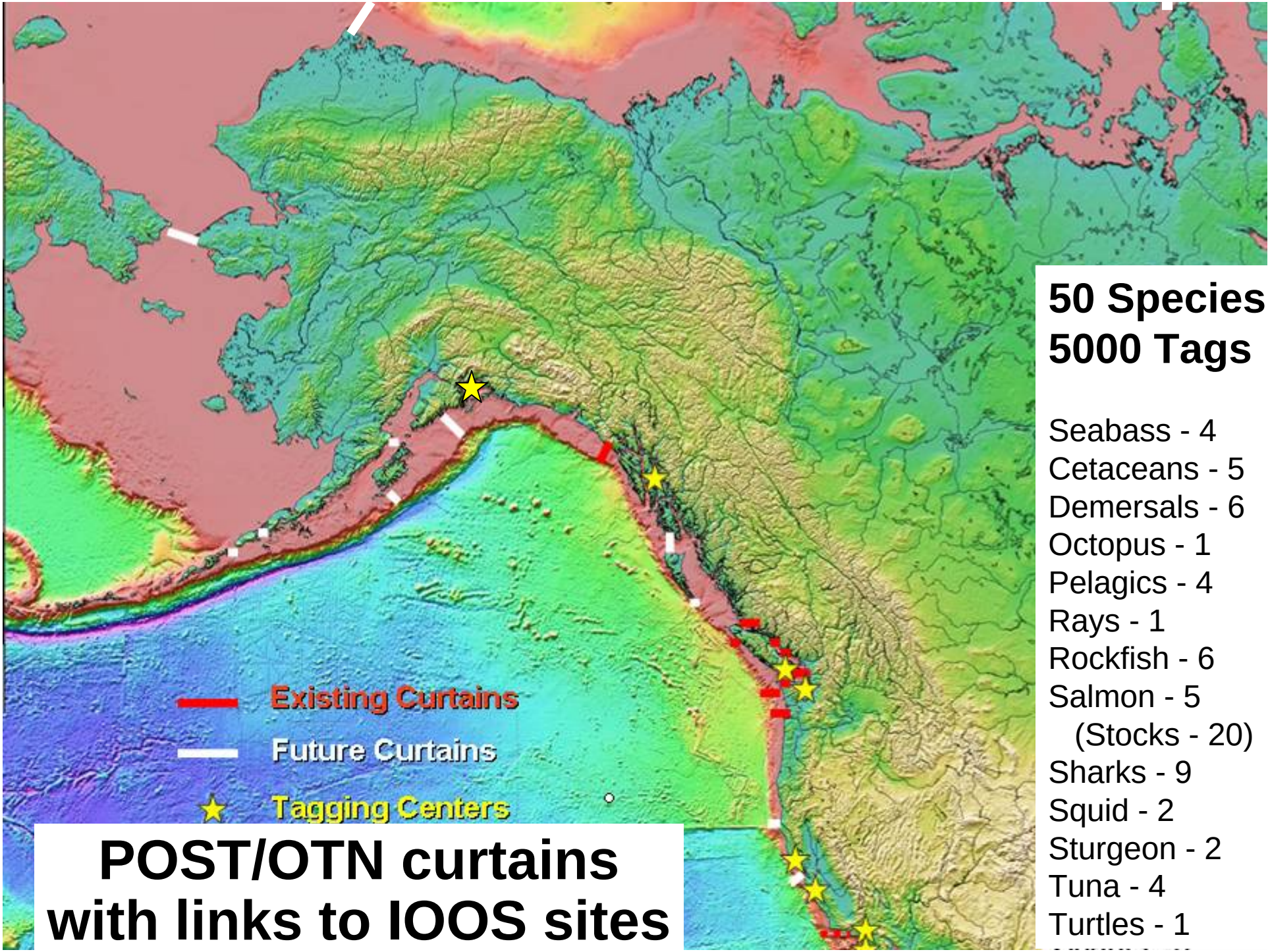


TOPP secret weapon #2
Elephant Seals

1,000,000+ TD profiles since 2000
Now CTDs, Pala, ‘06, *Science* 313



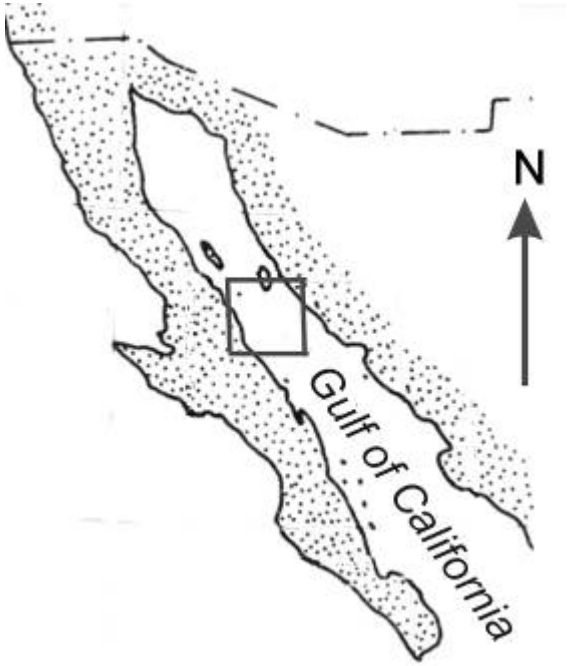




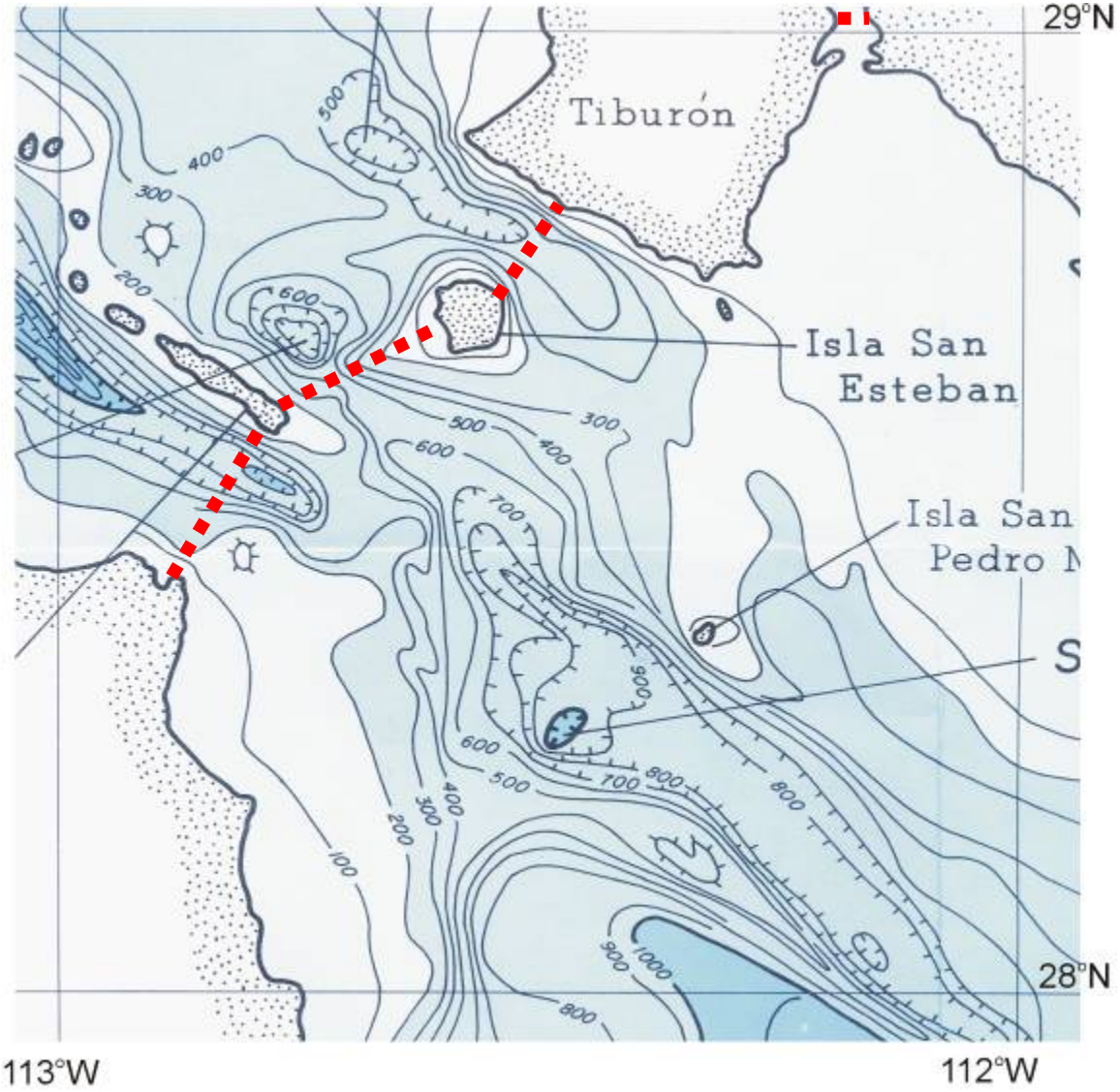
50 Species
5000 Tags

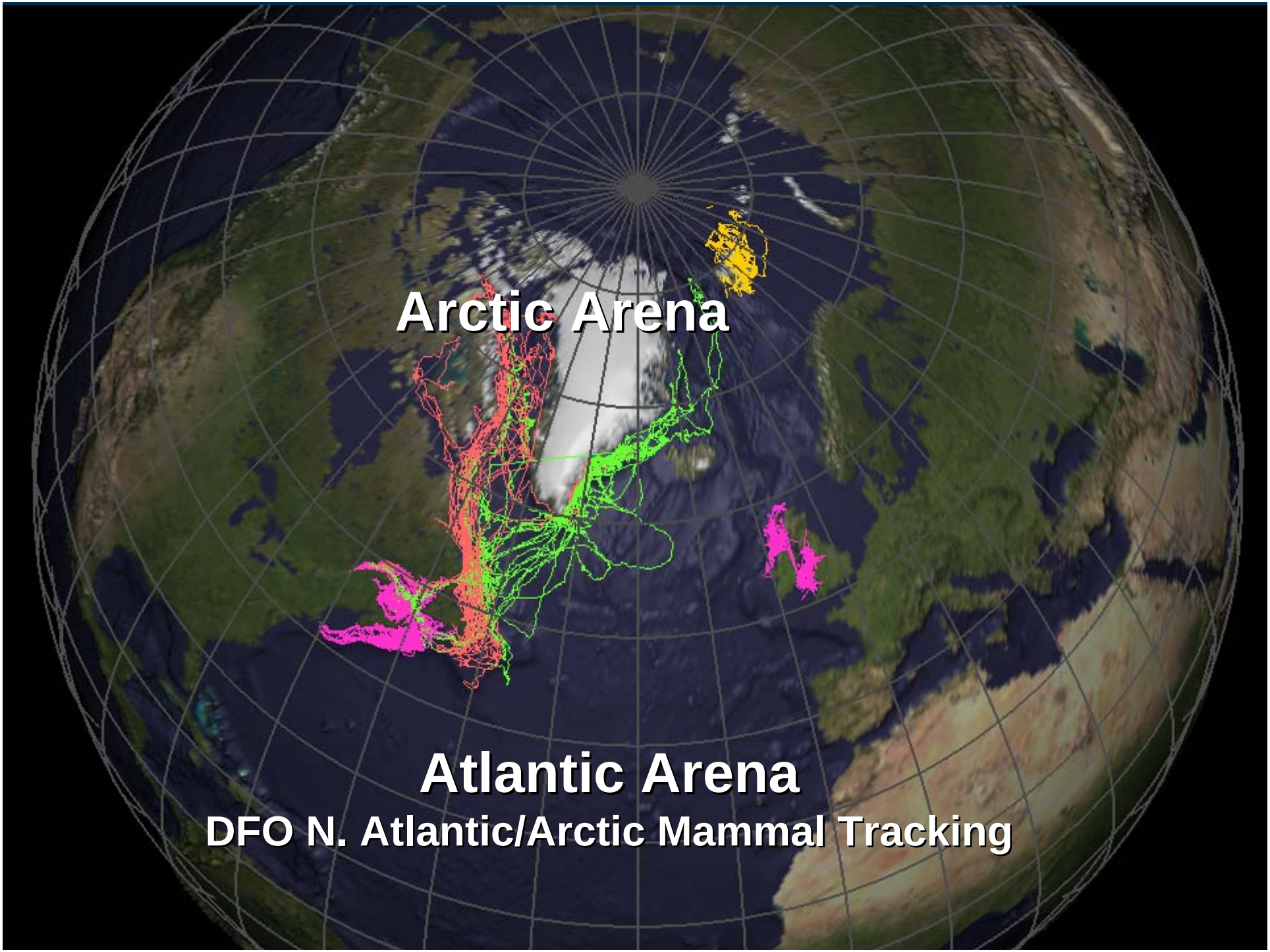
Seabass - 4
Cetaceans - 5
Demersals - 6
Octopus - 1
Pelagics - 4
Rays - 1
Rockfish - 6
Salmon - 5
(Stocks - 20)
Sharks - 9
Squid - 2
Sturgeon - 2
Tuna - 4
Turtles - 1

POST/OTN curtains with links to IOOS sites



One of the most productive regions in the world ocean




Arctic Arena
Atlantic Arena
DFO N. Atlantic/Arctic Mammal Tracking

April 16, 2007

SCIENCE

The Washington Post

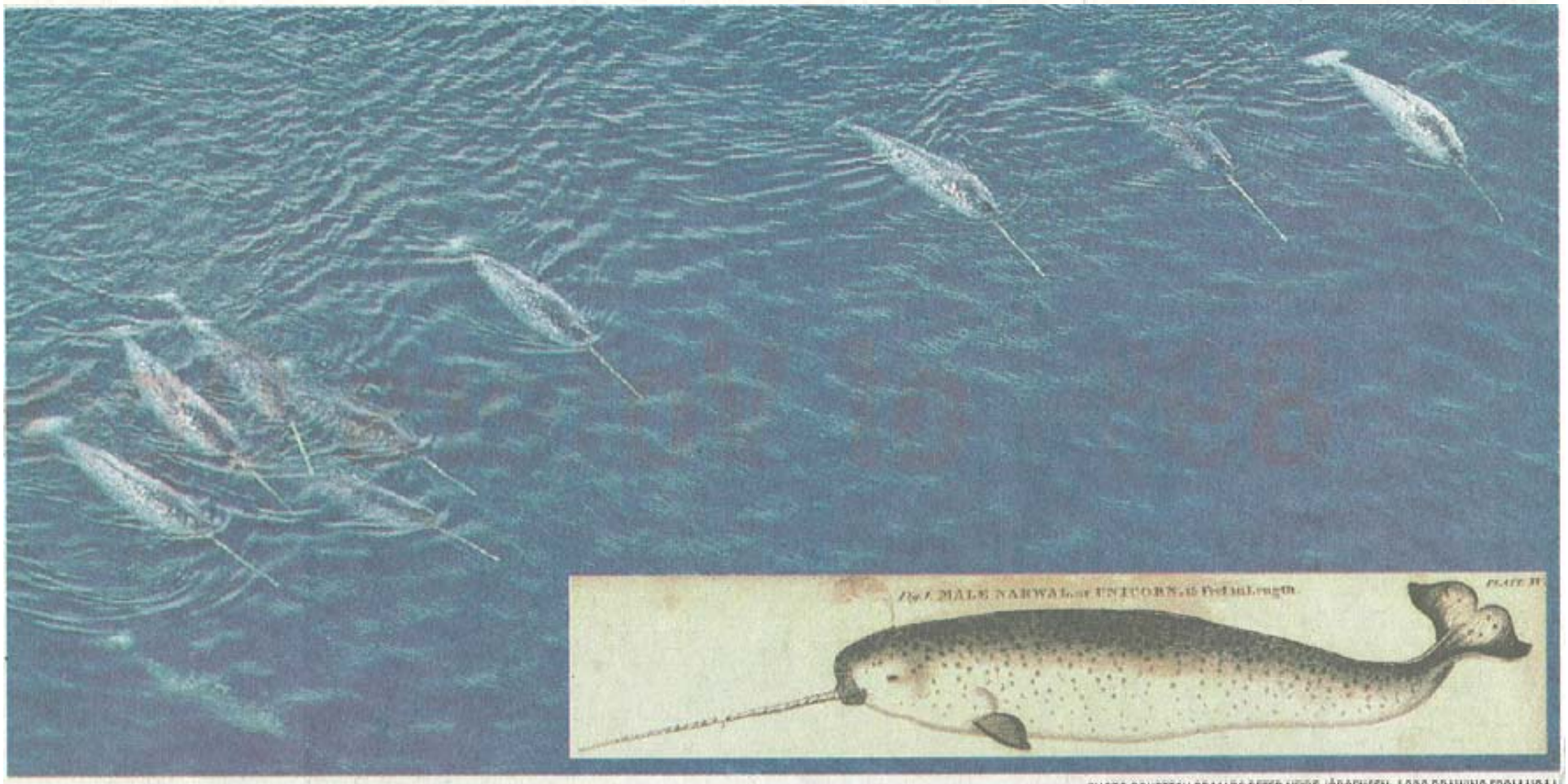
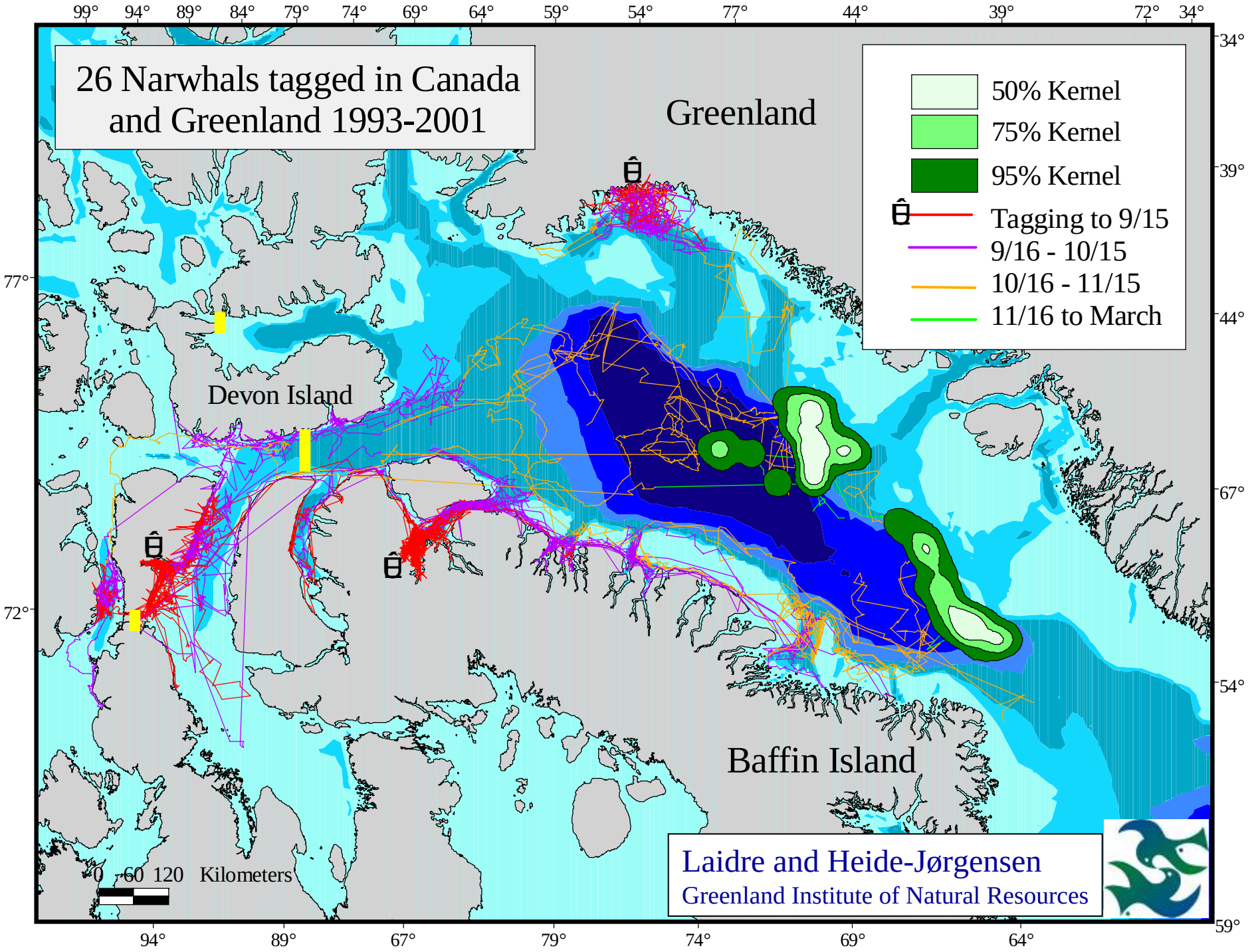


PHOTO COURTESY OF MADS PETER HEIDE-JÖRGENSEN; 1820 DRAWING FROM NOAA

A pod of male narwhals congregates in the summer near northwest Greenland. The whales migrate in the autumn to offshore ice-covered wintering territory in Baffin Bay and Davis Strait, where they feed on bottom-dwelling Greenland halibut more than a mile under the surface.

Tracking Narwhals in Greenland

August 2006 - March 2007

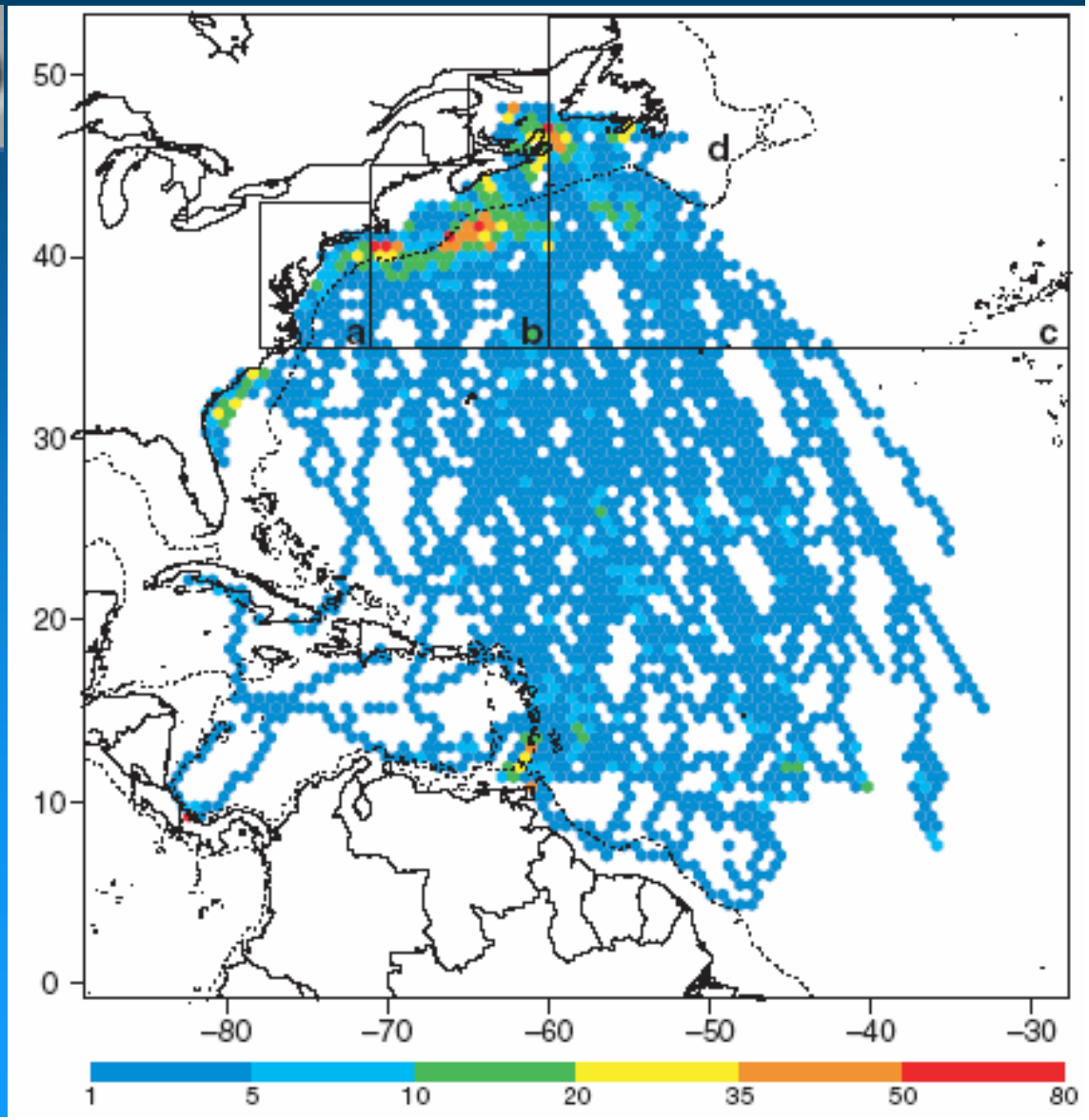

26 Narwhals tagged in Canada and Greenland 1993-2001
Greenland
50% Kernel
75% Kernel
95% Kernel
Tagging to 9/15
9/16 - 10/15
10/16 - 11/15
11/16 to March
Devon Island
Baffin Island
0 60 120 Kilometers
Laidre and Heide-Jørgensen
Greenland Institute of Natural Resources
99° 94° 89° 84° 79° 74° 69° 64° 59° 54° 77° 44° 39° 72° 34°
34° 39° 44° 67° 54° 59°
77° 72°
94° 89° 67° 79° 74° 69° 64°

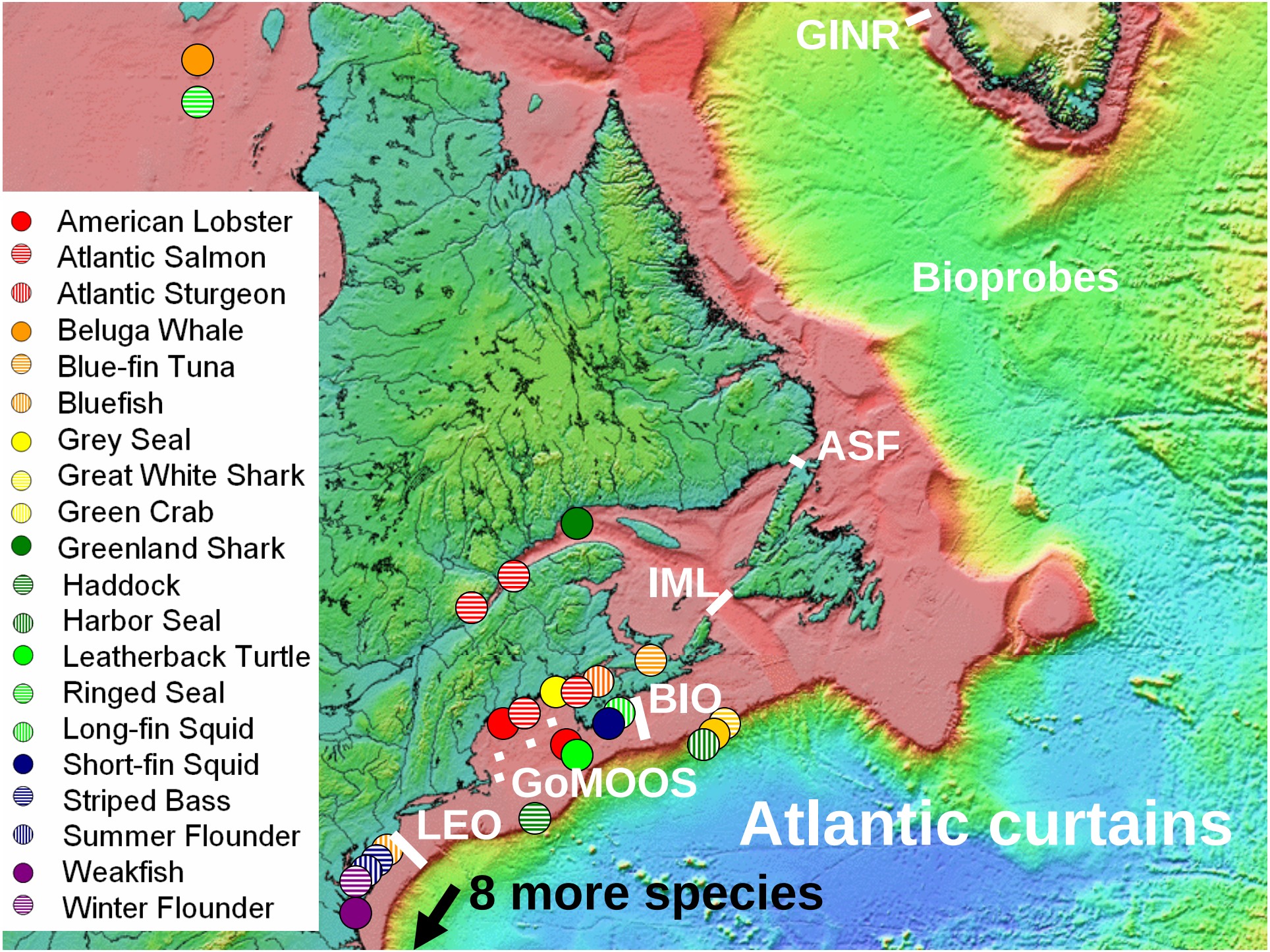
Tracking reveals threats to leatherback turtles in high-use habitats in northern waters

EMAP

Spatial use
38 turtles

James, Ottensmeyer & Myers
Ecology Letters, 2005




American Lobster
Atlantic Salmon
Atlantic Sturgeon
Beluga Whale
Blue-fin Tuna
Bluefish
Grey Seal
Great White Shark
Green Crab
Greenland Shark
Haddock
Harbor Seal
Leatherback Turtle
Ringed Seal
Long-fin Squid
Short-fin Squid
Striped Bass
Summer Flounder
Weakfish
Winter Flounder
GINR
Bioprobes
ASF
IML
BIO
GoMOOS
LEO
Atlantic curtains
8 more species

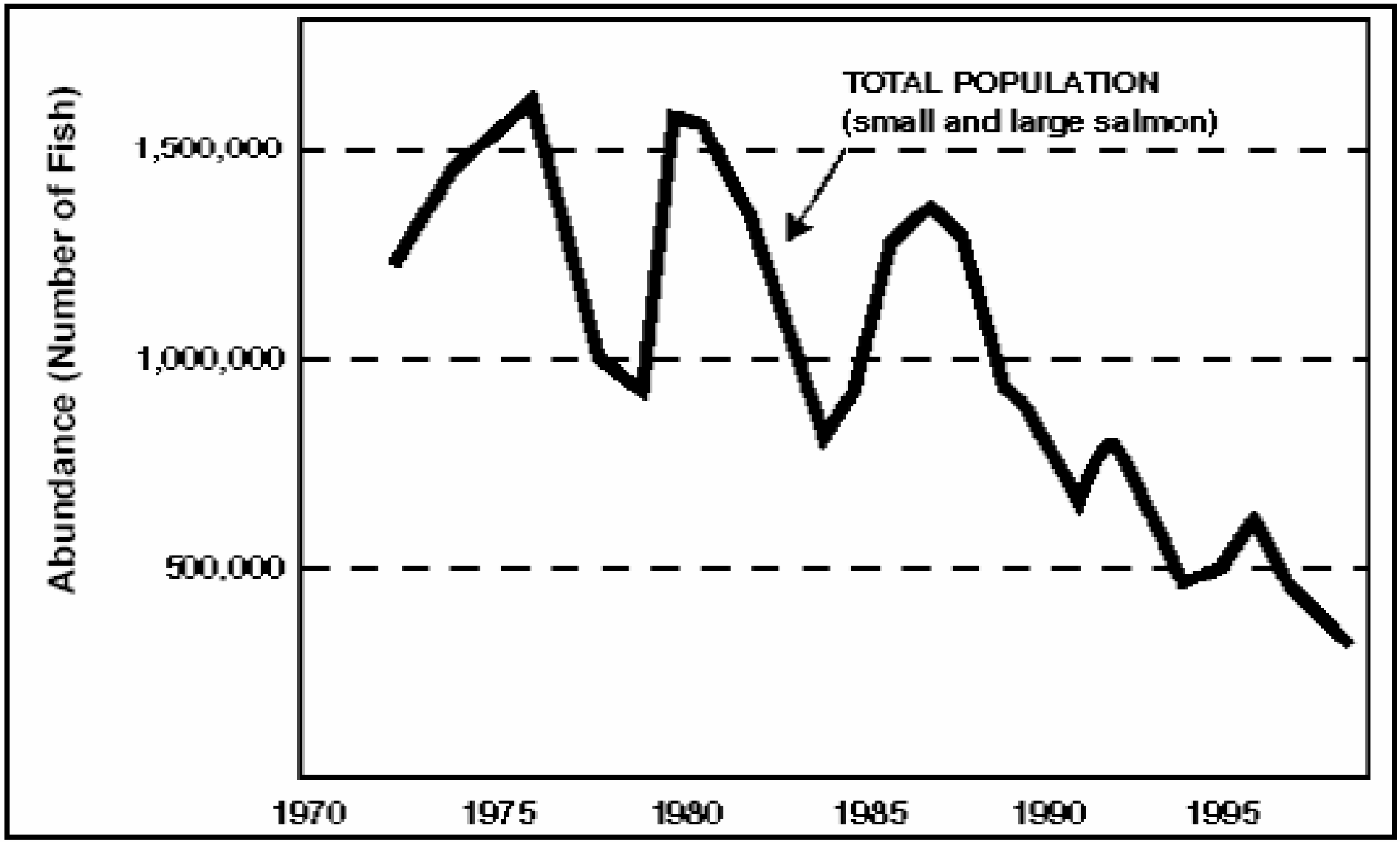
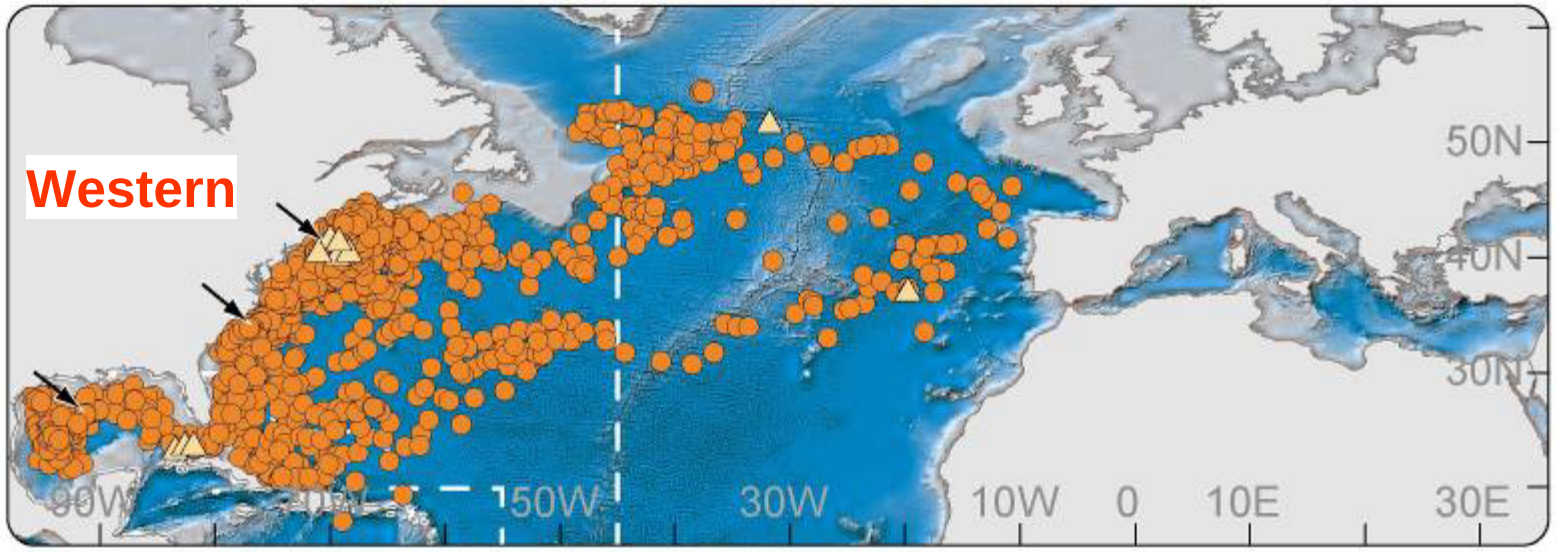


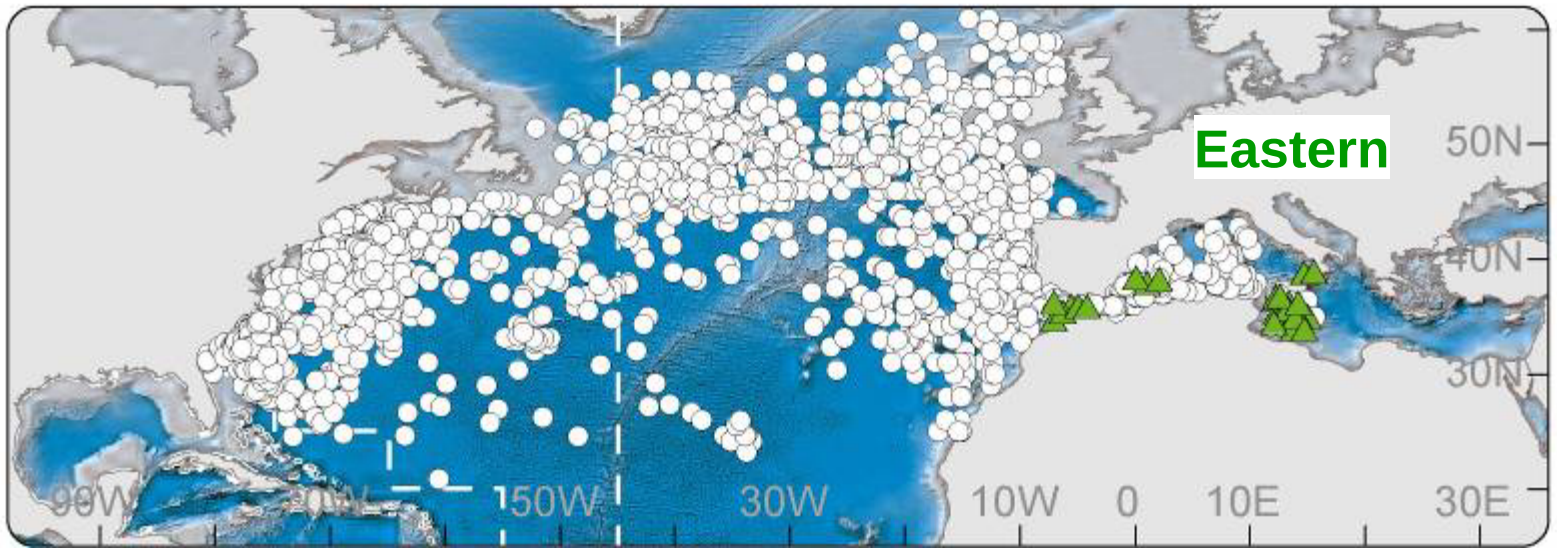
Figure 1. Numbers of Atlantic Salmon returning to North American Rivers.

Tagged bluefin tuna link Atlantic & Mediterranean - North America, Azores, Africa & Europe

Common feeding but separate breeding grounds

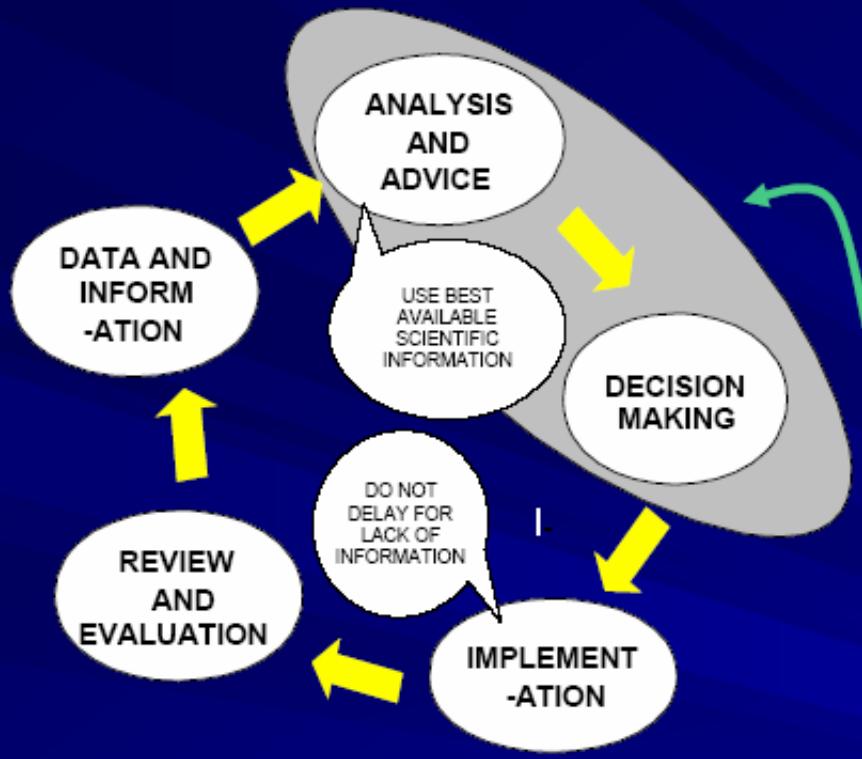


Block et al. Nature 2005



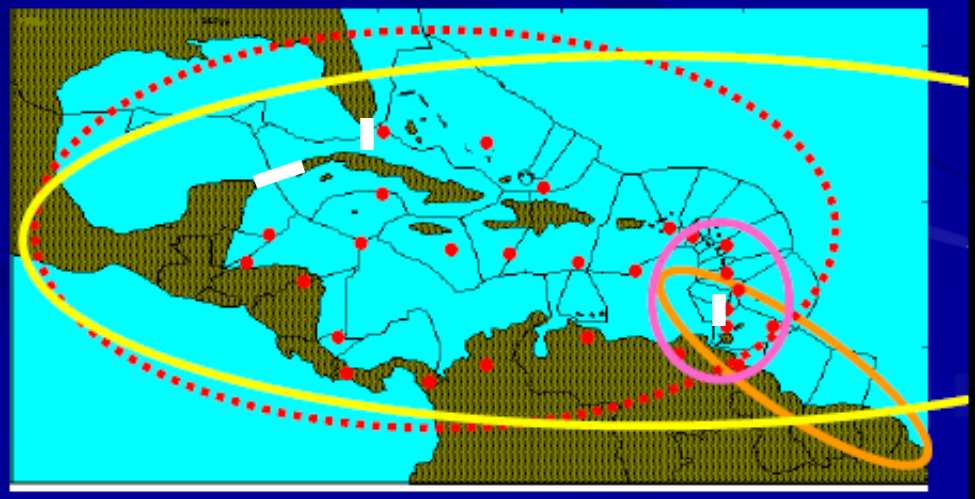
The Caribbean LME (CLME) Project

$7M UNEP Project
Lead – Lucia Fanning



CLME Project focus on governance is based on:

- The standard policy cycle
- Attention to scale issues



OTN Curtains

Large pelagics

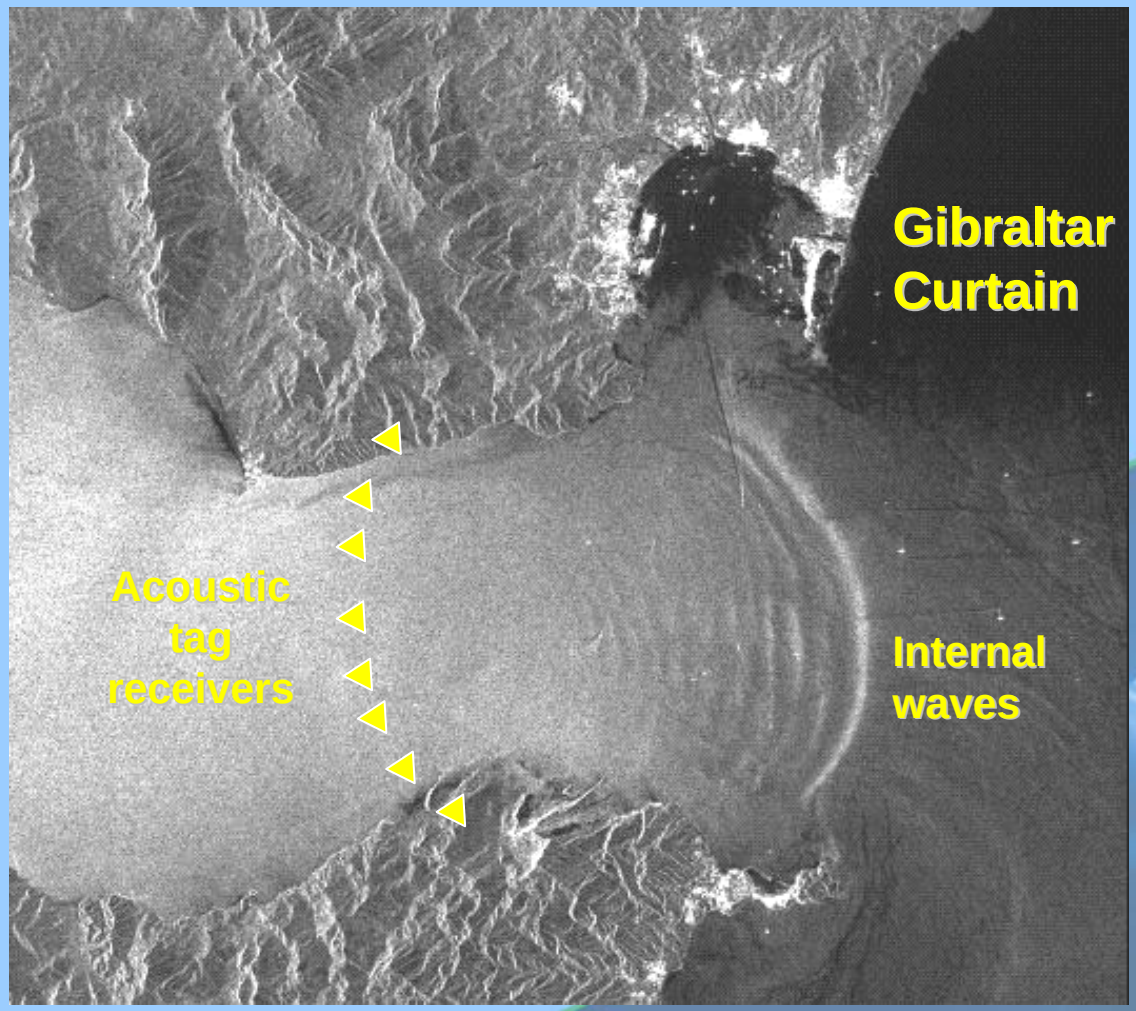
Reef fishes

Flyingfish

Shrimps

Lobster/Conch

Spanish, Moroccan, Portuguese, French Consortium – linked to EU CoastTrack

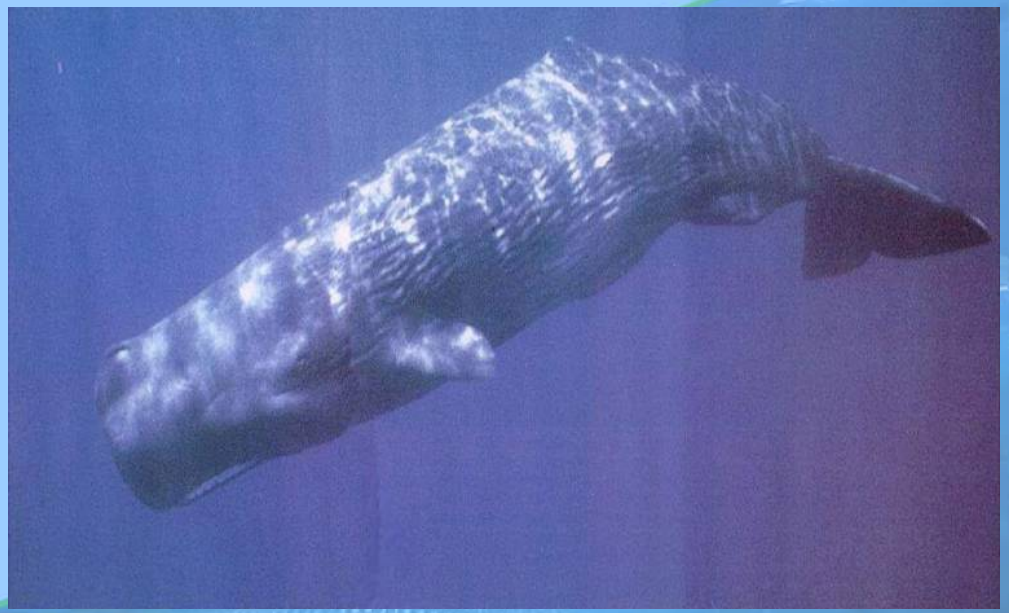


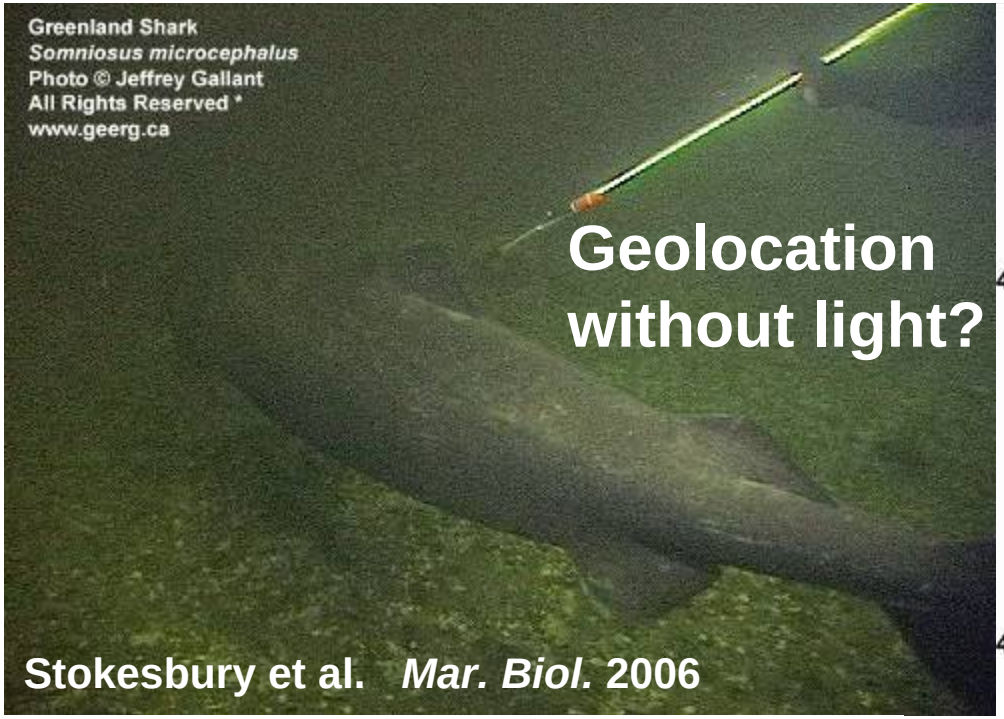
OCEAN TRACKING NETWORK

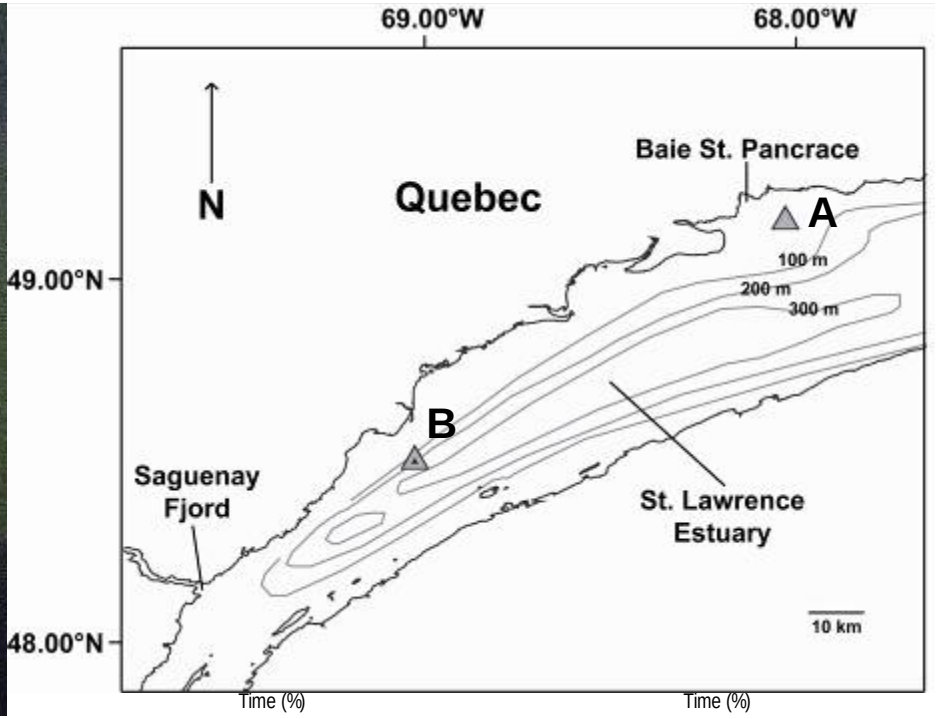
Parallel real-time monitoring of North Atlantic right whales?

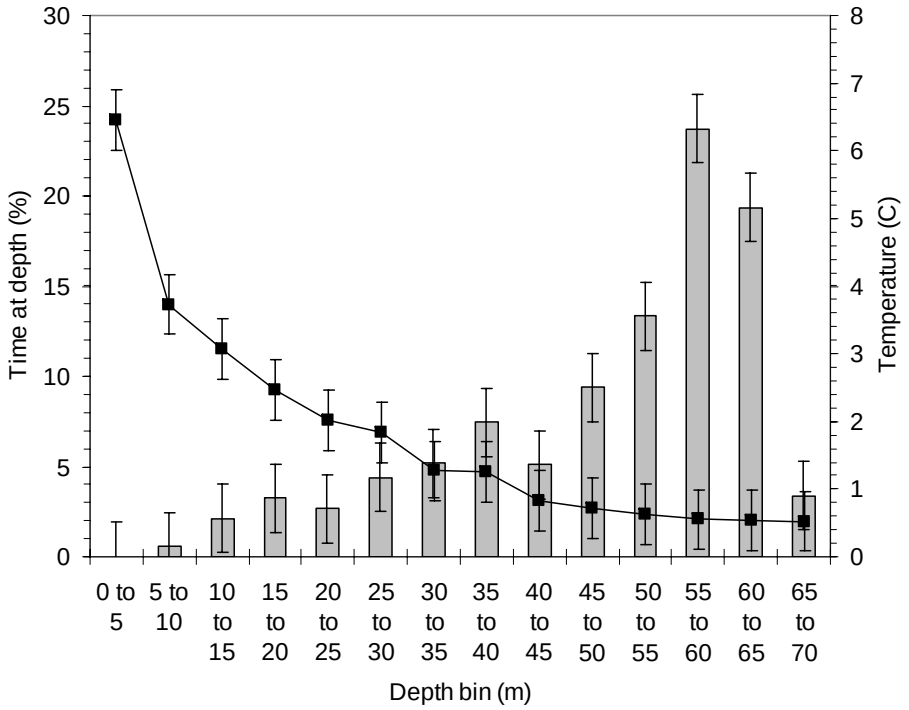
- Sperm whales use the Alboran Sea and the Algerian basin to feed on giant squid, but today the species is rare and elusive in the area, with boat traffic impeding its ability to detect prey

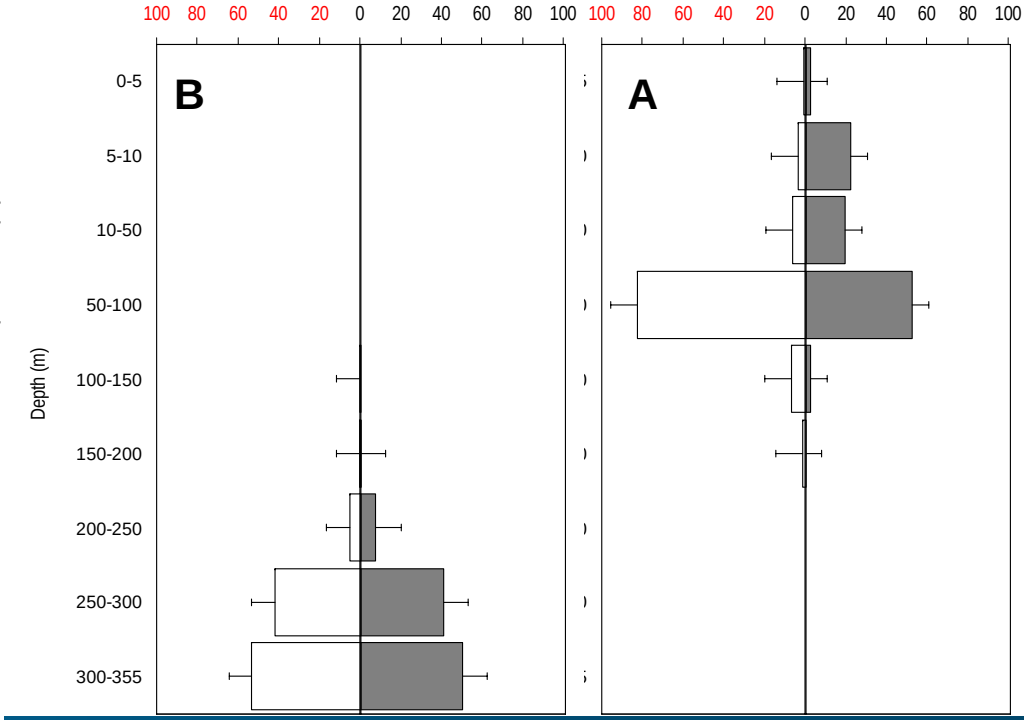
- Determining presence and movements of the few remnant individuals in the area is critical for understanding population biology and human impact




Greenland Shark
Somniosus microcephalus
Photo © Jeffrey Gallant
All Rights Reserved *
www.geerg.ca
Geolocation without light?
Stokesbury et al. Mar. Biol. 2006


69.00°W
68.00°W
49.00°N
48.00°N
N
Quebec
Baie St. Pancrace
A
100 m
200 m
300 m
B
Saguenay Fjord
St. Lawrence Estuary
10 km


Time at depth (%)
Temperature (C)
0 to 5
5 to 10
10 to 15
15 to 20
20 to 25
25 to 30
30 to 35
35 to 40
40 to 45
45 to 50
50 to 55
55 to 60
60 to 65
65 to 70
Depth bin (m)


Time (%)
Time (%)
B
A
Depth (m)
0-5
5-10
10-50
50-100
100-150
150-200
200-250
250-300
300-355

RAFOS – SOFAR

80-sec pong, 259.375-Hz – 260.898-Hz sweep
Triangulated positions. Rossby et al. ICES 2006